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INTERNATIONAL SEMINAR ON MODERNIZATION OF HOISTING MACHINES--RELIABILITY AND WORK SAFETY

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CYKLOCONVERTOR DRIVE FOR MINE HOIST

Summary. In the paper main parts of the ABB cycloconvertor drive were described such as: synchronous motor, frequency convertor,field exciter, supply transformers and control system. Function of this type of drive and comparison between merits of dc drive and just tachled were also given. In the further part of the article a brief theory employed in the application of cycloconvertors was shown together with some problems of their diagnostics and protections.

1. Drive system

The cycloconvertor drive comprises the following main parts: (Fig.1)

- Synchronous motor of salient pole type and with sliprings.
- Frequency convertor of cycloconvertor type.
- Field exciter
- Supply transformers
- Main high voltage circuit breaker
- Control system

The drive can be designed either as 6-pulse or as 12-pulse configuration. The ABB cycloconvertor drive is always of the 12-pulse type. Fig. 2 illustrates a 12-pulse parallel solution in which two separate windings in the motor are supplied by separate six pulse convertors. Fig.3. shows a motor of the type used.

The drive performance of the cycloconvertor drive for mine hoist is excellent and offers a number of advantages compared to a DC hoist drive.

The armature circuit is brushless, that is the limitations of a DC commutator do not exist.

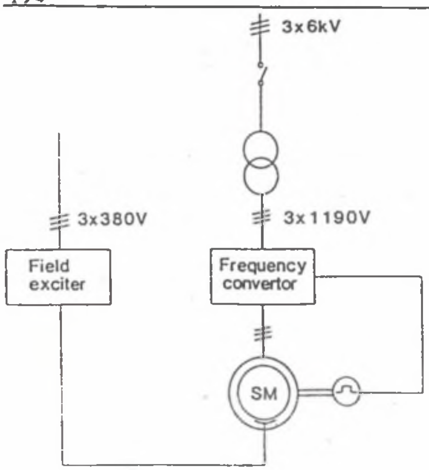


Fig 1.

Frequency controlled synchronous motor drive.

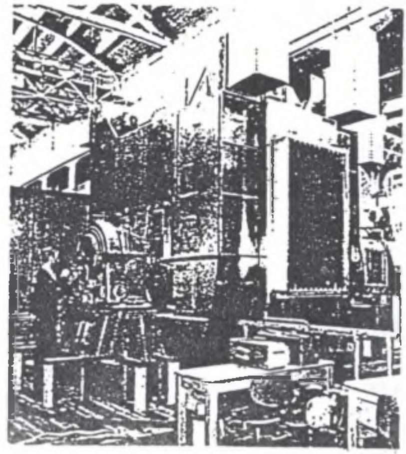


Fig 3.

Synchronous motor 7500 kW in work shop.

CYCLOCONVERTOR SYSTEM 12-PULSE

Parallell

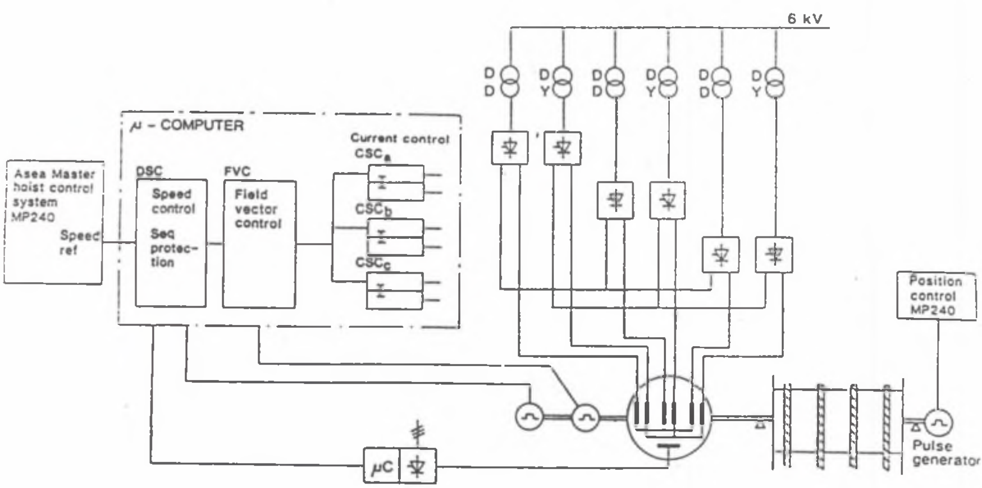


Fig 2.

- The synchronous motor has a larger air gap, which facilitates the shaft dimensioning and erection.
- The synchronous motor can be made shorter which allows for a shorter free shaft part.
- The cycloconvertor efficiency is higher than a corresponding DC-drive.
- The cycloconvertor drive is microcomputer controlled throughout, which allows for an outstanding monitoring and diagnostics of the drive.

Mine hoist drive motor

The three phase synchronous-motor is designed for cycloconvertor operation.

The motor will be delivered without shaft and bearings for mounting on the shaft of the hoist.

The hole of the rotor hub is tapered to suit the hoist shaft. The rotor is forced on to the shaft with the aid of hydraulic pressure and without any preheating. Hydraulic pressure is also used when the rotor is to be removed.

The motor is screen protected and splash proof, IP23.

It is separately ventilated; cooling air is forced into the rotor via separate air ducts and from the rotor through the stator to the outlet duct on the motor.

The outer panels of the motor can easily be removed to facilitate inspection and maintenance. The slip ring side is furnished with doors to provide access to the slip rings and brushes.

The base frame has been lengthened to enable the stator to be moved axially, thus providing access to the rotor for the purpose of overhaul and/or repair.

The stator winding is a two layer diamond winding with coils impregnated with Vacuum-Pressure-Impregnation method. The rotor is a salient pole construction with laiminated poles and complete copper damping winding.

6 temperature detectors Pt-100 (2/phase) are situated in stator winding and two detectors in cooling air, one in inlet side and one in outlet side.

The motor is equipped with space heaters.

Frequency convertor

The frequency convertor is of type cycloconvertor. Each 6-pulse group is composed of three conventional DC-double convertors - one for each motorphase. See Fig.4.

Fig. 5 illustrates the layout of a complete 12-pulse cycloconvertor. The figure shows that the convertor is composed of standard DC double convertors for DC drives. This way of construction ensures an economic and well proven design.

The convertor is complete with trigger pulse amplifiers, current measuring devices for the current control, auxilliary power supply and cooling fan equipment.

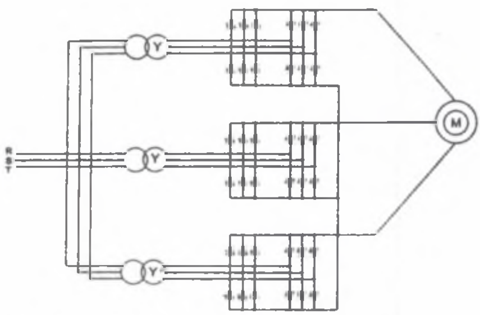


Fig 4. Cycloconvertor 6-pulse type

The 2 x three convertor modules are star connected. Consequently the AC supply must be galvanically seperated for each motor phase.

Field exciter

The field exciter is also a conventional three phase-6-pulse thyristor controlled rectifier of TYRAK L design. It is seperately supplied from a 3 x 380 V net. The DC-terminals are connected to the motor field winding via the slip rings.

The Tyrak L field convertor is fully digitally controlled by a micro-computer.

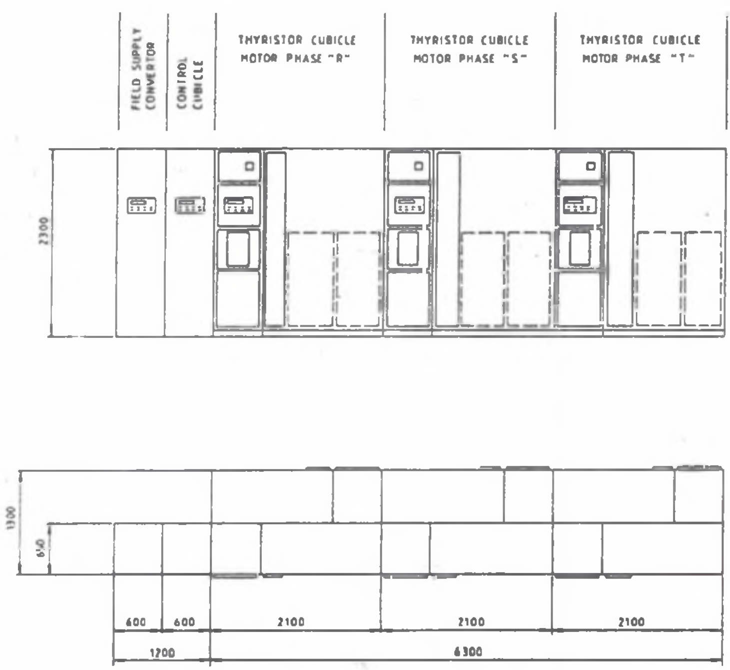


Fig. 5. Cycloconverter composed of 6 DC double convertors

Power supply

The cycloconvertor drive is normaly connected to a high voltage supply e.g. 6, 10 kV by a high voltage circuit breaker.

The supply is protected by instantaneous over current and overload relays.

Cycloconvertor control system

The drive control system is digitally controlled throughout from speed reference input to trigger pulse generation to the thyristors.

It is composed of seperate microcomputer systems.

- 6 Current controllers $CSC_{a, b, c}$
- 1 Field vector controller FVC
- 1 Drive system controller DSC

Each computer system is a single board computer unit to which I/O and interphase cards can be connected. Fig.6.

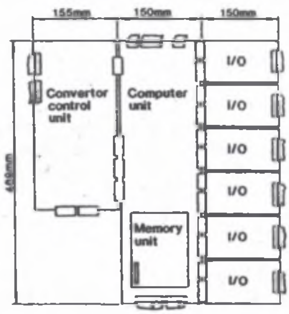


Fig. 6 . Phase computer system

Fig.2 shows a drive system layout in which also the separate functional control parts are indicated.

The task of the convertor system is to produce a current vector I to be impressed into the motor. This current vector is composed by three AC-phase currents I_a, I_b and I_c. In order to realize the three current sources, each phase convertor module has a current control system realized in a micro computer.

The field vector control system is deriving a model of the flux and current properties in the motor and calculating the angle between these two vectors. The field vector control system produces phase current demands to the current controllers in such a way that the above mentioned load angle will be 90^o.

The drive system controller DSC contains speed control, flux control, drive system sequencing, protection, diagnostics and communication with the overridning ABB Master mine hoist control system.

2. Function

Fig.7 shows the composition and function of the drive control system for each 6-pulse groups.

CONTROL SYSTEM CONFIGURATION

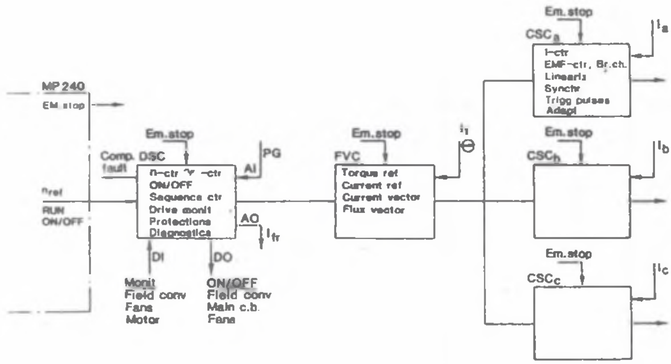


Fig 7. Control system configuration

Brief theory

The motor properties magnetic flux Ψ and magnetomotoric force I may in a three-phase system be represented by rotating vectors $\bar{\Psi}$ and $\bar{I}$. The shaft torque of the motor is the vector product between $\bar{\Psi}$ and $\bar{I}$.

$$T = \bar{\Psi} \times \bar{I} .$$

The main flux is generated in the rotor field winding, that is to say the flux vector Ψ is rotating synchronously with the rotor.

To be able to control the motor torque it is therefore necessary to produce a current vector $\bar{I}$ rotating synchronously with the rotor but displaced 90^o from the flux $\bar{\Psi}$. For this purpose the motor is equipped with a rotor position encoder, which provides information of the rotor axis position Θ.

The rotor coordinate system (d, q) is shown in fig. 8, which also indicates the flux vector location.

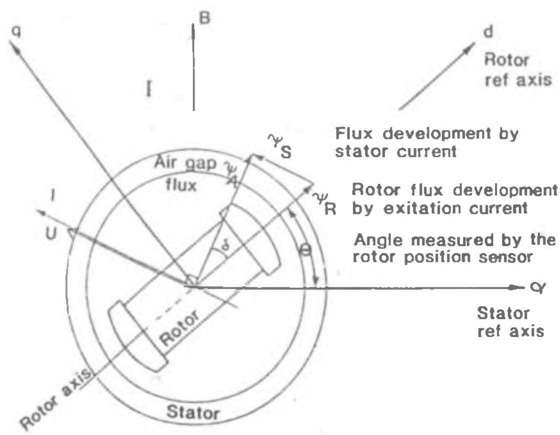
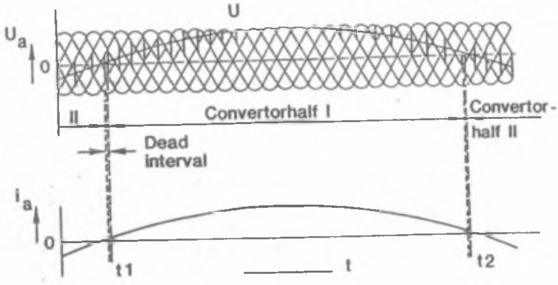


Fig. 8 . Coordinate systems in rotor and stator

Phase current control ($CSC_{a,\ b,\ c}$)

The task to impress an AC current into the motor is achieved by the current controlled convertor. Each phase convertor unit produces a sinusoidal phase voltage (in steady state) (Fig. 9) and the closed loop current control ensures that the convertor gets a current source action.



Output voltage U_a and current I_a of cycloconvertor
Power factor $\cos\varphi = 1.0$

Fig. 9 . Cycloconvertor output phase voltage

This means that the motor current will accurately follow the three sinusiodal current commands produced by the overriding field vector controller. (FVC.)

The dynamic requirements of the current control are very high:

- The bridge change time has to be very short in order to maintain a correct phase angle.
- The adaptaion of the controller between discontinuous and continuous current is essential.
- A linearization of the voltage - control signal is also a must.

These requirements are best acomplished by a digital control system with high calculating performance. The microcomputer for this function is working with a sample time of about one and a half millisecond.

Field vector control (FVC)

The field vector control is the functional center of the drive control. The unit forms a motor model and calculates the flux vector (amplitude and phase angle), and produces reference signals for armature currents (Iar, Ibr, Icr) as well as feed forward signals (Eh_a, Eh_b, Eh_c)

Fig.10 shows a functional block diagram of the field vector control.

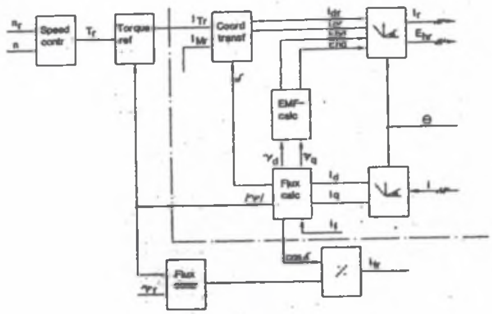


Fig 10. Field vector control system

The control and calculations are made in rotor coordinates. Input as well as output signals therefore have to be transformed from stator - to rotor coordinates and vice versa. This is achieved by the blocks to the right in fig.10. Sinusoidal signals (e.g. I_a, I_b, I_c) in the stator will appear in rotor coordinates as DC-signals.

Fig.11 illustrates a step in a phase current I_a and the same signal as it appears in the rotor (I_d).

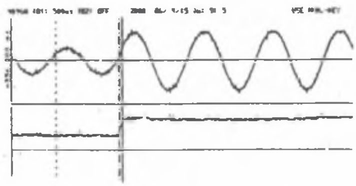


Fig.11. Phase current I_a and its representation in the rotor I_d

The current vector is represented in a cartesian system (d.q. See fig 8 and 10) as its components I_d and I_q.

The flux calculation function generates the d and q components of the flux Ψd and Ψq as well as the load angle δ between rotor and flux vector.

By means of the load angle δ it is also possible to determine the current references, first in rotor coordinates I_{dr}, I_{qr} and then transformed to stator coordinates I_{ar}, I_{br}, I_{cr}.

In order to get a quick stator current control it is essential to use an EMF-feed forward, which is also generated in the field vector control system.

Drive system controller (DSC)

To coordinate the different parts of the drive system a drive system controller is used. The functions is illustrated as a block diagram in fig.12.

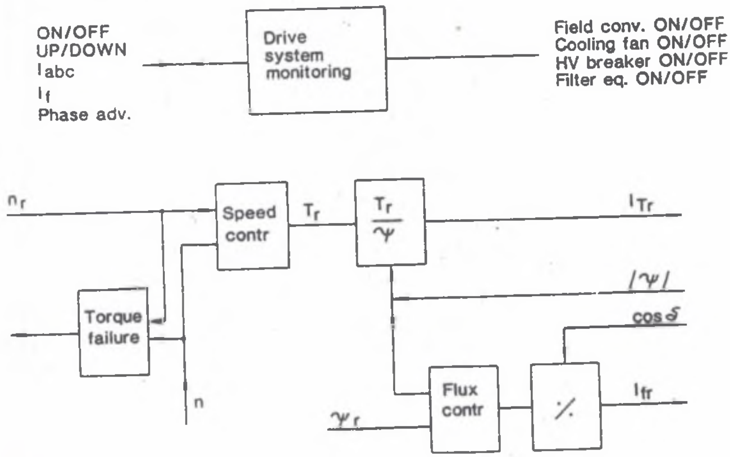


Fig.12. Drive system control

The unit works as an interphase between the overriding mine hoist computer and the drive. It contains functions for ON/OFF, RUN, blocking, and drive protection.

The unit also contains the control of speed and flux.

The speed reference is transmitted from either a manual operator lever or via a series communication link from the ABB Master mine hoist control computer.

A digital pulse transmitter on the motor shaft is by an I/O unit transferred to the DSC. The speed reference and the actual measured speed value are processed in the speed regulator, which then generates a torque reference signal T_r. This signal is devided by the flux Ψ and a reference signal I_{Tr} is formed. This signal represents the current reference component producing torque in the motor, that is to say it is perpendicular to the resulting flux direction.

The flux regulator works with a fixed flux reference Ψ_r and a closed loop control of actual flux value Ψ. The actual flux value is calculated in the field vector control (FVC) as described earlier.

The output signal is adapted by $\cos\delta$ in order to get a quick field current response.

Operation

The drive system includes a very powerful operator's panel with a liquid crystal graphic display. Fig.13.

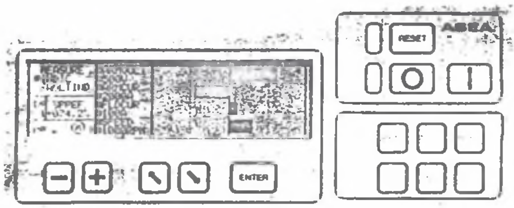


Fig.13 . Operators panel

This panel is used for all communication between the operator and the system and replaces pushbuttons, analog meters, reference potentiometer and fault indication display.

The information is presented in legible text with quantities in physical units. Diagnostics, status checks, signal logging, fault messages with first fault indication and fault statistics are some of the features available through the operators panel.

The operators panel can also be used for:

- Commissioning
- Parameter setting

The panel can graphically dispaly for example a step response for tuning the speed controller at commissioning. The time and amplitude scales can easily be changed for a suitable resolution.

The operators panel can be located in the convertor door, or in an operators console.
The infromation can be presented in Swedish, English, German or French, per the operator's choice.

Status check and diagnostics

Due to the use of microcomputers the drive has got a very extensive system for status check and diagnostics.

Status check:
Indication of selected values are displayed on the operators panel as bar charts. Four signals can be displayed simultanouesly. The max reading value can simply be reprogrammed during operation.

Fault indication:
Fault messages are given in clear text, in a chosen language, and with first fault indication.
The system supervises the operation and records abnormal conditions:

- Functional protection such as earth fault, overload and loss of pulse-transmitter signal

- PC-board supervision. Malfunctions are indicated with board type and location.

- Sequences and commands are monitored and evuluated. If an order is not acknowledged within a predetermained time, an error message is given.

Fault statistics:

Up to 99 primary faults are recorded together with the times when they occured. These can be displayed whenever required, or they can be printed out on a printer.

Logger:

The logger is a software function used to record some of the important variables during operation.
Six different signals can be recorded at the same time, each signal with an independent measuring interval. The logger stores 186 values per signal, and can be used as a trend recorder. In case the operation is interruped, the logger can be programmed to record a certain number of values after the event. This provideds a unique possibility to analyze what actually happened just before and/or after the system failure.
The logger information can be displayed grahically on the operators panel, or be transmitted to the overriding ABB Master computer.

Commissioning and maintenance

The convertor is designed for simple commissioning and maintenance.
The graphic operators panel and the keyboard, mounted on the convertor door are excellent aids for the commissioning engineer. He can make parameter settings and function selections via the display. He can also tune the controllers by entering step disturbances in the reference signal and trace the result graphically, all via the display.

Also maintenance is greatly simplified, with all the information on the display in legible text. No computer adapted codes are used, which menas that the operators do not need to have any computer knowledge.

3. Protections

The drive is equipped with protection devices to such an extent that a safe operation is ensured.

The principle is that each part of the drive reports to the drive control system, where proper action is taken depending on the art of failure. The drive includes the following protections

Drive system

- Emergency stop
- Earth fault main circuit
- Earth fault auxilliary supply
- Torque failure
- Undervoltage supplies
- Speed feed back loss

Power supply unit

- Instantaneous overcurrent
- Thermal overload

Frequency convertor

- Instantaneous overcurrent
- Thermal overload
- Phase sequence
- Overtemperature convertor
- Control system faults

Field exciter

- Instantaneous overcurrent
- Thermal overload
- Phase sequence
- Control system fault
- Minimum field

Motor

- Overtemperature

Recenzent: Doc.dr inż. Jerzy Hickiewicz

Wpłynęło do Redakcji w maju 1992 r.

NAPĘD CYKLOKONWERTOROWY DLA GÓRNICZYCH MASZYN WYCIĄGOWYCH

S t r e s z c z e n i e

W artykule przedstawiono główne zespoły napędu cyklokonwertorowego firmy ABB takie, jak: silnik synchroniczny, przemiennik częstotliwości, wzbudnik pola, transformatory zasilające i system sterowania. Opisano sposób funkcjonowania tego typu napędu i porównano jego zalety z zaletami napędu prądu stałego. W dalszej części artykułu wyjaśniono podstawy teoretyczne stosowania cyklokonwertorów oraz przedstawiono zagadnienie ich diagnostyki i użytych zabezpieczeń.

ЦИКЛОКОНВЕРТЕРНЫЙ ПРИВОД ШАХТНЫХ ПОДЪЁМНЫХ МАШИН

Р е з ю м е

В статье представлены основные узлы циклоконверторного привода фирмы АВВ , такие как синхронный двигатель , преобразователь частоты , генератор поля , силовые трансформаторы и система управления . Описан способ функционирования этого типа привода и сопоставлены его преимущества с преимуществами привода постоянного тока . Далее в статье выяснены теоретические основы применения циклоконверторов , а также проблема их диагностики и использованных систем обеспечения.