Variable-speed drives for belt-conveyor systems

A project report of the revamp of a lignite conveyor line

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Introduction

More and more frequently, modern belt-conveyor systems are equipped with variable-speed drives on the basis of frequency converters connected with standard squirrel-cage motors and gearboxes. As compared with conventional drives used in constant-frequency systems they have the major advantage that both power consumption and mechanical wear can be significantly reduced. This makes it possible, in conjunction with powerful control and process management systems as well as modern diagnostic tools, to design efficient belt-conveyor systems characterised by low operation costs and high availability.

Fig. 1: View of a coal conveyor

This is the description of such a drive concept covering five belt conveyors implemented recently by ABB. For the first time ABB Automation has used here grid converters according to the latest developments of drive technology.

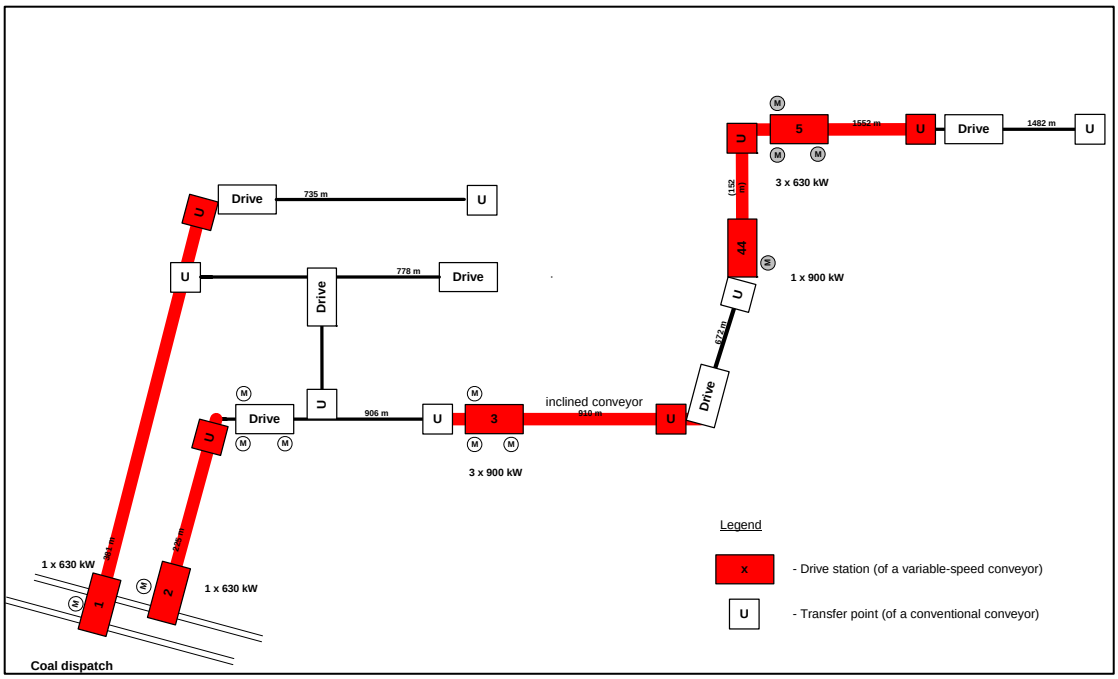

Fig. 2: Belt-conveyor scheme

Quality criteria
Introducing speed control for belt conveyors, the customer has defined precise economic and technological objectives:

- power savings through a load-dependent control of the belt speed
- efficiency increase
- minimisation of system perturbations
- reduction of gear and belt wear

Demanding quality criteria have been specified as benchmarks for accomplishing those objectives. They include in particular:

- dynamic torque characteristics at starting and stopping
- efficiency with different belt speeds and loads
- power factor ($\cos \varphi \geq 0{,}95$)
- system perturbations (THD $\leq$ 10%)

ABB Automation, the supplier of the electrical-engineering part of the system, could successfully prove that all agreed criteria have been attained.

	Efficiency of the whole system (incl. transformer, frequency converters, motors & air conditioning)	
M/M_N [%]	**stipulated in contract [%]**	**proved [%]**
	at 100% speed	
100	**90.1**	**92.4**
75	**90.2**	**92.0**
50	**89.2**	**90.6**
	at 75% speed	
100	**89.8**	**91.3**
75	**90.0**	**91.1**
50	**89.1**	**90.3**
	at 50% speed	
100	**88.3**	**89.0**
75	**88.7**	**88.7**
50	**88.1**	**88.4**

Fig. 3 Efficiency

Drive technology

All conveyor drives are equipped with HXR type six-pole totally enclosed fan-cooled squirrel-cage motors fed by ACS 600 frequency converters. They are low-voltage drives for a supply voltage of 690 V, all designed for 4-quadrant operation, i.e. working as motors and generators. The electrical energy generated during the braking process is fed back into the grid through grid inverters.

Fig. 4: Motor HXR 450 LM6

Two different concepts have been implemented on the frequency-converter systems, depending on the number of motors in question:

- single drive
- multi drive

While the single drive, simply speaking, consists of one grid-side and one motor-side inverter, the multi drive is more complicated. Here one diode rectifier and one grid inverter each feed in parallel on one common DC busbar which, in accordance with the drive configuration, supplies up to three inverter units.

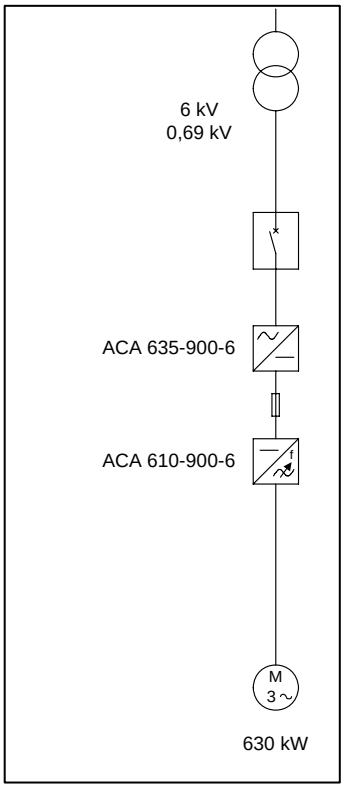

Fig. 5: Single drive

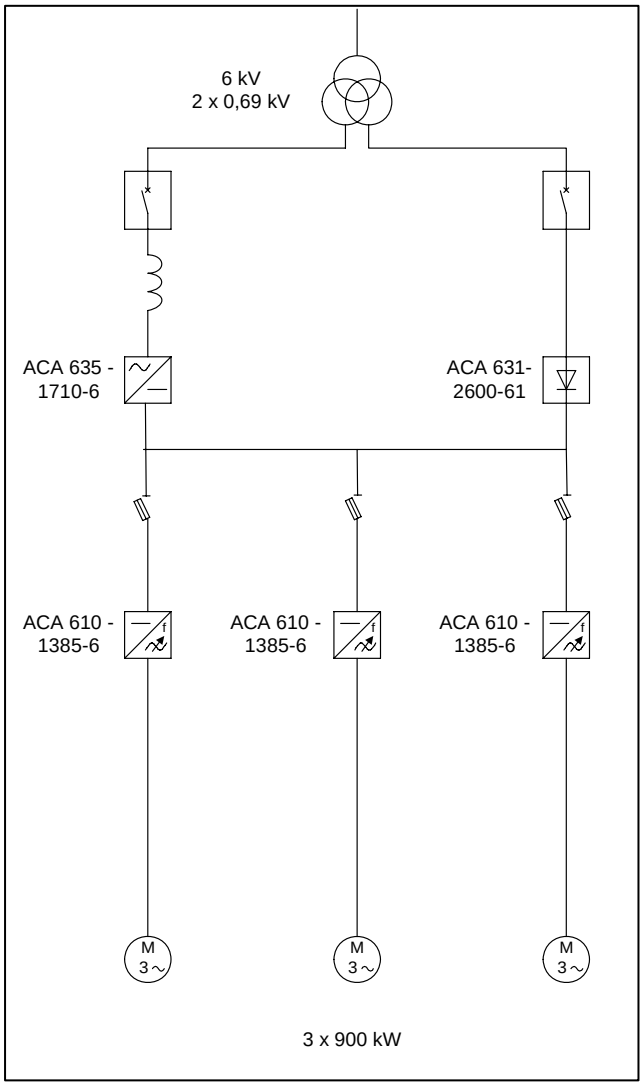

Fig. 6: Multi drive

All the ABB frequency converters used are based on IGBT power semiconductors and are characterised, in particular, by a modern control concept called direct torque control (DTC®). Contrary to the well-known pulse-width modulation (PWM) the DTC® controls directly the torque and stator flow of the motor. That lends the drive a higher control accuracy and better dynamic properties, especially in the starting and braking phase.

Guiding principles for dimensioning the drives have been not only the mechanically required torque but also the objective to use common hardware as far as possible. Another important criterion has been the demanded high availability of the system. This is why a so-called emergency operation has been foreseen for the multi drives, permitting the continued use of the conveyor system with reduced performance in case of failure of a supply unit or inverter.

The equipment of the belt-conveyors is shown here:

Conveyor	Motors		Frequency converters		Remarks
	number type HXR…	performance synchronous speed	supply unit 1 type rated current supply unit 2 type rated current	inverter type rated current	
1	1 450 LM6	630 kW 1000 min^{-1}	ACA635-0900-6 695 A	ACA610-0900-6 755 A	supply unit: grid inverter
2	1 450 LM6	630 kW 1000 min^{-1}	ACA635-0900-6 695 A	ACA610-0900-6 755 A	supply unit: grid inverter
3	3 500 LR6	900 kW 1000 min^{-1}	ACA631-2600-6 2176 A ACA635-1710-6 1320 A	ACA610-1385-6 1156 A (3x)	supply unit 1: diode unit supply unit 2: IGBT grid inverter
4	1*) 500 LR6	900 kW 1000 min^{-1}	ACA631-2600-6 2176 A ACA635-1710-6 1320 A	ACA610-1385-6 1156 A (2x) *)	supply unit 1: diode unit supply unit 2: IGBT grid inverter *) final stage: 3 x 900 kW
5	3 500 LR6	630 kW 1000 min^{-1}	ACA631-2600-6 2176 A ACA635-1710-6 1320 A	ACA610-1385-6 1156 A (3x)	supply unit 1: diode unit supply unit 2: IGBT grid inverter

Fig. 7: Drive design

Owing to the arrangement in closed and insulated electric containers it is necessary to get the loss heat out that is produced by the frequency converters. Split-type air conditioners have been installed for that purpose with a particular view to having closed cooling circuits. This has led to an almost total elimination of dust from the interior of the frequency converter room being deposited on the power-electronic components.

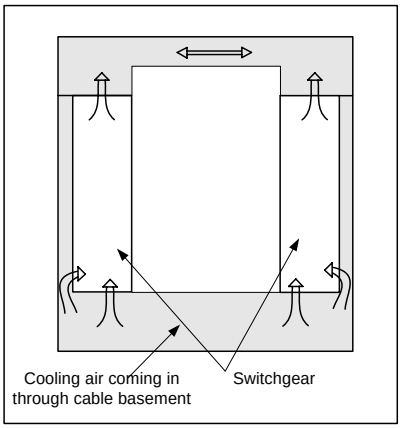

Fig. 8: Container cross-section

Control concept

Compact programmable controllers – so-called application controllers (APC) are integral parts of the frequency converter system. These controllers are used for time-critical control and supervision functions close to the drives, such as

- conveyor speed control
- speed control of individual drives
- speed and belt-slip control
- load equilibration between two driving drums
- speed difference control between two motors on one driving drum

Thus the application controllers are the interface between the frequency converters and the decentralised control system based on *ABB Advant OSC*® that performs overriding operation control functions and general control and supervision tasks.

Optimum belt load

An optimum loading of the belts is achieved by way of controlling the belt speed, depending on the load volume, in the range of 3.0 … 6.0 m/s. A laser scanner is used to supply reference values by monitoring the cross-section of the load on the belt.

The value determined is the input for a complex mathematical model called “virtual conveyor” integrated in the control system. It is there that the reference values are calculated for all downstream conveyors and transmitted via Ethernet (optical-fibre connections) to local controllers and from there to the frequency converters.

Diagnostics

Every frequency converter system has an interface for DrivesWindows®, a powerful Windows-based software tool for commissioning and maintenance. DrivesWindows® runs on conventional personal computers or laptops and is easy to handle. It covers the following functions:

- displaying and editing of signals and parameters (online or offline)
- storing of parameters
- recording and graphically displaying of signals
- recording of fault and failure reports with time stamp

In addition, the frequency converter systems are equipped with a touch screen for fast menu-supported display of major operational signals, such as speed, torque, fault and status reports.

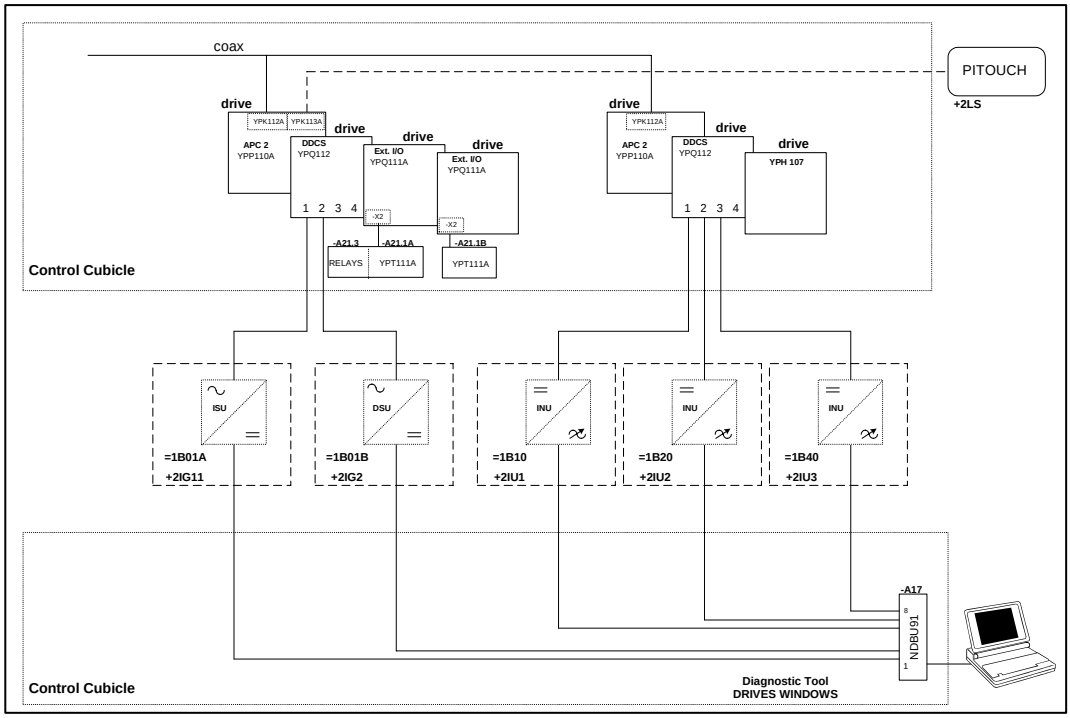

Fig. 9: Diagnostic tools on a conveyor

Summary

Some of the benefits of controlled drives are

- an optimum loading of the belts through controlling the belt speed, depending on the load volume, in the range of 3.0 … 6.0 m/s; reference values are supplied by a laser scanner monitoring the belt load
- a reduction of gear and belt wear through smooth starting and stopping of conveyors
- the elimination of belt slippage at driving drums
- more even torque on driving drums through load equilibration
- control of speed differences between motors on one driving drum

Moreover, the electric drives are characterised by high availability and efficiency as well as little system perturbation.

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