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## CUTTING INVESTMENT COSTS BY USING A NEW SOLUTION OF SPEED CONTROLLED BELT CONVEYER WITH AVAILABLE MEDIUM VOLTAGE 6 KV-SLIPRING-MOTORS

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### 1. Background

When Vattenfall Europe Mining AG (former LAUBAG), in “Welzow Süd”, Germany, decided to modernize the overburden conveyor systems of its open pit coal mine, the main goals were to minimize wear and to optimize the installed power of variable speed drives (VFD). To reach the brown coal, an excavator has to remove 60 to 120 meters of surface overburden onto a chain of conveyors that move out of the pit area to a stacker. The conveyor is the most energy efficient solution of moving the 115 to 119 million cubic meters per year over several kilometres. The conveyor follows the excavator as it moves with the expanding mining area, making the size and total weight of the complete drive system on the conveyor head station crucial to its operation. Excess weight would require significant investment to reinforce the mechanical structure. Optimization of conveyor loading during operation within the technological limit parameters by using variable conveyor speeds is another goal for the customer.

Drives in the mine operation with 2 MW 6 kV frequency converter PF7000 Rockwell Automation and 6 kV-squirrel-cage motors are already in operation for overburden conveyor systems of Vattenfall Europe Mining AG. In the lignite mine of Welzow-Süd were 19 drives installed since 2000.

### 2. The new challenge

The traditional slip ring (or wound rotor) motor solution was characterized by high maintenance, a load dependent acceleration with some limitations and no continuous con-

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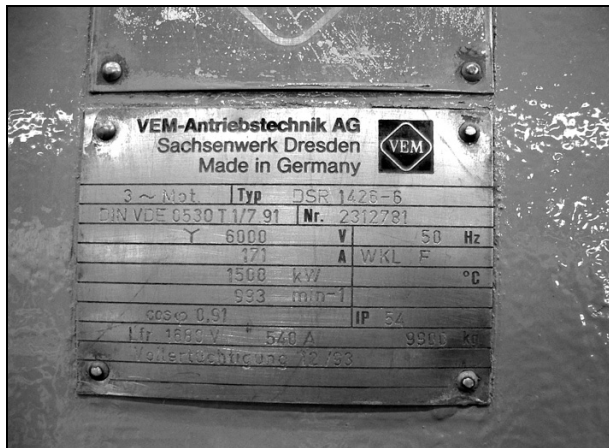
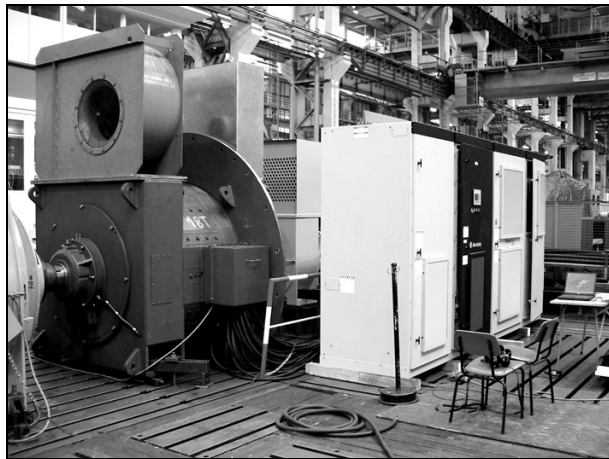
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veyor speed control. The new, variable speed solution had to start and accelerate smoothly independent of load without slipping the belt on the drums, even with overload. The load has to be equally shared on all attached motors at all times, but particularly during acceleration and deceleration.

As weight and cost are key issues, re-use of existing components and lightweight new equipment is essential. Line side harmonic standards EN6100-2-4 and power factor ( $\cos(\phi)$ ) greater than 0.9 for the operating speed range of 50 to 120% of nominal speed had to be met.

Under this conditions BEA and Rockwell Automation had to develop a new solution by using both – 6 kV slip ring motors and 6 kV Allen-Bradley® PowerFlex® 7000 medium voltage AC drives (Fig. 1).



**Fig. 1.** Existing 6 kV-slip-ring motors in the VEM Sachsenwerk workshop during the load tests on an Allen-Bradley® PowerFlex® 7000 medium voltage AC drive

### 3. Solution

To meet these challenges, Vattenfall Europe Mining AG turned to technology leader Rockwell Automation and installation experts BEA for the medium voltage drive solution that is lightweight and allows the use of either standard motors or retrofitting existing slip ring motors at 6.6 kV. There are a lot of motors in the spare part stocks and workshops of the customer available.

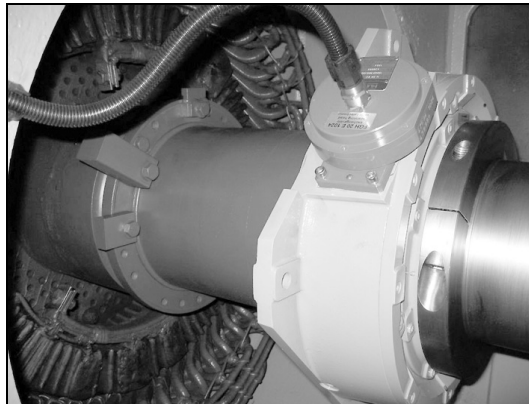
The first step was an extended test of existing 6 kV slip ring motors in the laboratory of VEM Sachsenwerk Dresden. The test of 900 and 1500 kW DSR Motors comprised high-voltage tests such as parameters like  $\tan \delta$ , vibration, noise emission and harmonics tests under no load and full load conditions.

The second step was an extended test of 6 kV slip ring motors in double or parallel operation, i.e. two motors on one shaft parallel on one frequency converter PowerFlex® 7000.

The manufacturer states: there are no doubts to use these slip ring motors in TWIN or single operation on a 6 kV Allen-Bradley® PowerFlex® 7000 medium voltage AC drive. During the test it could be measured thermal and harmonic stress similar to line operation of the motor.

This new technology is called “TWIN-DRIVE”.

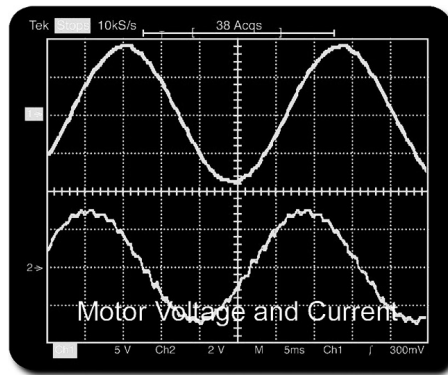
In 2006 BEA and Rockwell Automation got the order for the refurbishment of an  $6 \times 1.5$  MW belt conveyor station A205 from Vattenfall Europe Mining AG. After this retrofit the conveyer is operating with  $2 \times 2$  MW on two 2 MW VFD's and  $2 \times 900$  kW on one 2 MW VFD's (Fig. 2).



**Fig. 2.** Refurbishment of the motors contains the re-mount and short circuit of the slip ring and install an incremental encoder

Rockwell Automation leads the trend toward reduced size and weight of drives with its compact Allen-Bradley® PowerFlex® 7000 medium voltage AC drive. The cabinet size on

a 1.5 to 2.5 MW drive is 3.5 to 4 meters and has a weight of 3.5 to 4 tons. The innovative technology of the pulse width modulation (PWM) rectifier impressed Vattenfall Europe Mining representatives. The PWM rectifier does not require an individual rectifier duty transformer. Instead, it operates direct on the 6.3 kV line with a builtin AC line reactor, making the complete PowerFlex® 7000 drive system the most compact, the most efficient and lightweight solution that saves approximately fifteen tons compared to previous liquid starters. The PWM rectifier also provides superior low-line harmonic distortion well within the EN 6100-2-4 and IEEE 519 guidelines, approved by on-site third-party line harmonic specialist. These low line harmonics avoid extra thermal stress in other transformers and motors, and issues with harmonic sensitive equipment. An unique feature of the PowerFlex® 7000 is the innovative PowerCage™, which reduces repair and shutdown time. The Power Cage houses all the main power components in a compact modular package and allows components to be replaced in less then five minutes.



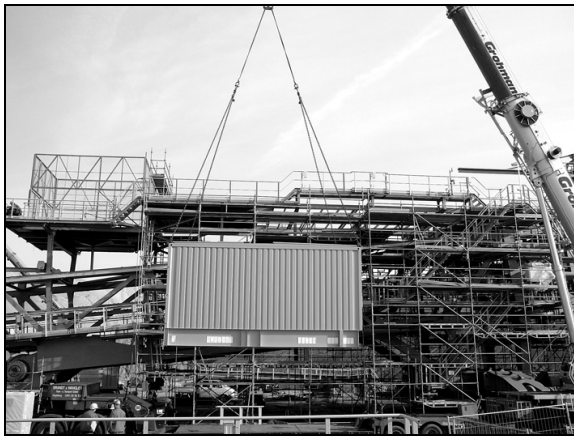
**Fig. 3.** The Direct-to-Drive feature mitigates common mode voltage stress and does not produce  $dv/dt$  or reflected wave voltage stress on motors

BEA is the solution provider of the key engineering for the electrical and automation equipment and has got a long experience with the refurbishment of electrical plants for mining machines like excavators, spreader and conveyors. Beside of the BEA engineering of the whole electrical and automation equipment, was the new design of the PowerFlex® 7000 medium voltage AC drive for operation with two refurbished slip ring motors. In addition to that there where some special measurements on the motor, like re-mount and short circuit of the slip ring necessary. This space is used to install an incremental encoder inside the motor houses.

In addition of the key drive solution the whole refurbishment of the conveyer station includes:

- engineering and documentation,
- mechanical refurbishment,

- installation of new isolated container based on air conditioned e-houses (Fig. 4),
- MV and LV switchgear systems,
- control system (PLC), and field bus system,
- data transmission by using Open Transport Network OTN,
- local control panels and safety devices,
- communication and radio system,
- installation of Diagnostic system for drives, PLC, Vibration measurement devices for mechanical equipment,
- commissioning, functional tests and training courses (on site).



**Fig. 4.** Container based on air-conditioned e-houses for MV-, LV-switchgears and converters as a basis for minimised downtime during the refurbishment and reduced maintenance efforts during operation of mining devices

## 4. Results

BEA Engineering and Rockwell Automation's drive solution offers significant benefits to the accelerating and decelerating conditions, as well as during continuous operation of the material transportation process. Rocks, water or technical problems can cause the whole conveyor chain to stop up to 20 times per day. The regenerating capability allows a fast and coordinated deceleration without heating up any braking components and without wasting energy. The coordinated deceleration avoids overloading at conveyor transfer points. Under all conditions, the overhead control ensures balanced load sharing between the two drives operating on a single drum and between separate drums. The ability of controlled and balanced torque means less stress, wear, and therefore less maintenance on the motor, gearbox and belts. „S” curve speed control during acceleration and deceleration also minimize belt dynamic interaction. The squirrel cage motors, tuned for VFD operation, have been factory tested at 97% efficiency at nominal speed and load. The PowerFlex® 7000 AC drive with PWM rectifier operates at nominal load with greater than 98% efficiency, with the auxiliary power supply and fan included. The ControlLogix-based „optimized conveyor loading” (OCL) ensures high system efficiency by using a material tracking system across the chain of conveyors, to continuously adjust speeds so that the conveyor belts are fully and uniformly loaded. A partly loaded conveyor with a higher speed than necessary, wastes energy and causes unnecessary wear.

As a result of high efficiency components and OCL, the overall operating and maintenance costs are heavily reduced. The most important benefit with respect to the overall project costs is the reduced amount of installed drive power. The same conveyor before modernization with conventional fixed speed drives required six units of 1.5 MW each, in total 9 MW. After modernization, this conveyor with a variable speed solution in a range of 50% to 120% and a 120% overload/overspeed capability moves at least the same amount of material with only 3 units of 2 MW each, for a total of 6 MW. Additionally, capital investment was reduced by re-using some existing equipment like the 10 MVA transformer. Reliability and serviceability are key issues for a mining business operating three shifts, six days per week, where a conveyor breakdown will stop the entire process. On-site medium voltage trained BEA service engineers guarantee a 4-hour response time and Rockwell Automation provided backup with a Global Manufacturing Solutions engineer, and dial-in access for additional diagnostics capability. Vattenfall Europe Mining AG demonstrates its confidence in the strategic decision to use MV VFD drives for mobile conveyors by the award of several more conveyor upgrade orders to the Rockwell Automation/BEA consortium.

By adjusting an optimized conveyor speed, a constantly high conveyor loading (OBB) can be achieved for an as careful as possible and energy saving operation.

A laser scanner installed at the excavator face conveyor predetermines the upper and lower limit of the control range. The conveyor speed is then adjusted within these limits depending on the loading.

The financial impact by using the TWIN-DRIVE Technology is clear:

- VFDs require less installed power than fixed speed drives under the same technological condition (17.000 tons per hour);
- VFDs allows extended belt length by the same installed power than fixed speed drives under the same technological condition (17.000 tons per hour);
- saving costs by 60-90T□ per motor;
- optimized conveyor load and high efficiency drive system reduces energy consumption;
- reduces stress and wear of mechanical equipment increases availability and cuts maintenance costs.

The results mentioned above are specific to Vattenfall Europe Mining AG's use of Rockwell Automation products in conjunction with other products. Specific results may vary for other customers.