Information and control systems in OKD coal preparation plants

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Abstract: The paper informs about control and information systems operated in OKD a.s. coal preparation plants in the Ostrava-Karviná region. ATP Soukup Ltd. has become the leading manufacturer and supplier of these systems to OKD. ATP Soukup is also a major supplier of measuring, regulating, and control equipment for coal preparation. ATP Soukup, being familiar with the state-of-the-art coal preparation technology and using the latest knowledge of technological process control, has developed comprehensive control systems used in coal preparation plants with all the necessary links to the company management and to external partner organizations. The paper analyses in more detail particularly the coal preparation control systems used in the Důl Lazy, Důl Darkov, and Důl ČSM coalmines. In the above mentioned coal preparation plants, also sales control systems have been implemented built upon existing coal preparation plant control systems that cover the area of product quality assurance. These systems are powerful tools that the coal preparation plant workers may use to optimize production and assure product quality to meet the ISO 9000 standards.

Key words: automation, technological process control, coal preparation plants, VMS, sales control

1. Conception and objective of the control system

For all the implementations of our control systems in coal preparation plants, the decisive factor was the control of the key preparation technologies such as heavy-liquid separation, jigging and flotation as well as the control of dewatering and storing technologies. The solution of local technology control paved the way for controlling a coal preparation plant as a whole, monitoring

the performance and efficiency of each technology, controlling the key quality parameters, recording the output of the entire coal preparation plant per hour, shift, and day as well as calculating the key economic figures. The installed coal preparation plant control system could be used as a basis for sales control. The technological process of storing the washed coal is directly linked to the process of loading and transport and, in co-operation with shipping and receiving departments it forms a sales control department. The sales control is then closely followed by quality control, which goes back against the flow of material through the whole coal preparation process. The quantity and quality of the sold product must meet the parameters agreed in contracts with customers. To accomplish this, quality must be assured throughout the whole technological process.

2. Control system levels

Figure 1 depicts, in a simplified form, the system of production control in a mining company as a set of interconnected and co-operating blocks. Adding the flow of information and production to the picture, we obtain a logical distribution of production and quality control into control levels.
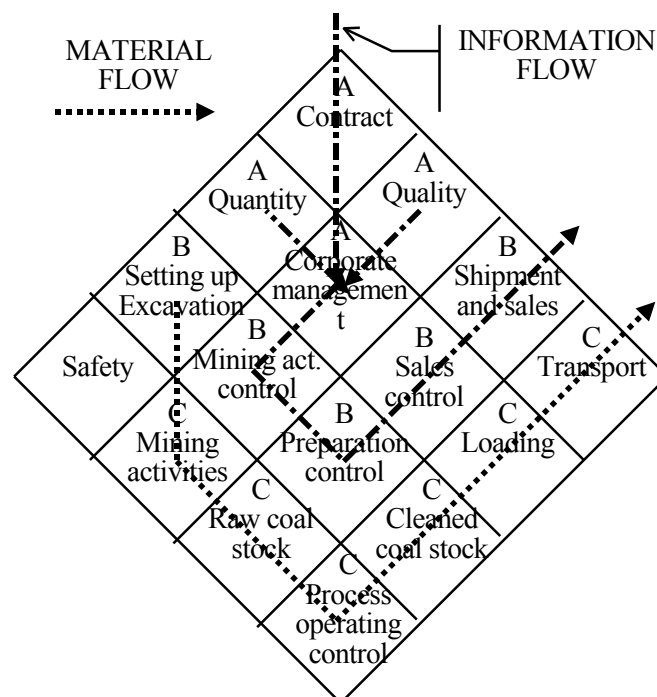

Fig. 1. System of production control in a mining company

In accordance with this conception, we have adopted the following distinction of control levels for building the system: *process level*, denoted by the letter C in the figure, *production management (dispatching) level*, denoted by the letter B, and *top management level*, denoted by A.

The terminology is based on the degree of participation of man in the control process. The stratification into control levels has no direct bearing to the system's architecture in terms of the configuration of technical resources or to the structure of the system program solution.

The process level is closely linked to the technological process. Human participation is restricted to monitoring and setting the control parameters. This particularly applies to direct control of technological nodes in distributed control units and with automated data input.

The centres of the production management control are typically placed in control rooms for traffic, loading, foremen offices, etc. where the users can access information on the progress of the controlled process. Current data from the process level inform on the current state of a technological process. The production management level data provide summarising and control figures related to a shift or a day. They are mostly calculated and verified to get an overall view of the controlled process as a whole.

This control level is sort of automatically assigned to the company management level. In our conception, it is also extended to lower-level control structures, to be employed by leading workers in coal preparation plants and sales departments. To these people, a number of tasks are available to provide them with views of the production and marketing progress from different angles and over a long period.

3. Systems of coal preparation plant control

The development of each of these control systems was part of a large project aiming to provide a comprehensive solution of technological processes up to the production management level. Its implementation comprised the following areas:
− modernizing and completing the sensor equipment,
− finding solution to automatic control of the main technological nodes,
− building an automated control and information system.

3.1 Sensor equipment of the system

The ATP Soukup control system operates about 1200 (ČSM) to 1600 (Darkov) analogue, binary and counter sensors. Part of the sensors customised for coal preparation plants are the company's own development.

Typical **analogue sensors** are, for example, those measuring the specific mass of sludge and magnetic suspensions, continual ash meters on conveyers, ash meters for flotation gangue, current load values for conveyer weighers, turbidity meters, meters of magnetic proportions in suspensions, machine load meters, and level indicators.

Binary sensors are mostly point level indicators, machine contactor contacts or end switches.

They form the bulk of the sensors involved in the system.

Counter sensors are used, for example, to register the output from a conveyer weigher.

Apart from these physical sensors, the system also operates a number of "virtual sensors", which are combinations of real switches and derived values calculated by the system.

3.2 Automatic control of the main technological nodes

As part of the system installation, the main technological nodes were automated. Here are some examples of technological nodes automated by our company:

3.2.1 Flotation automation

The flotation process is controlled by dosing the flotation agent according to the ash content of the flotation gangue with a correction using the rate of flow and the specific mass of the input raw material. As a stabilising element for the main control circuit, the level in the flotation machine is regulated by controlling the flotation gangue output.

The flotation control has been developed over a long period. The original local control in an analogue version was replaced by direct computer-based control, which allowed easy setting of technological parameters or a change of algorithm in the event of considerable changes in the raw material. The implementations in coal preparation plants are always tailored to the local conditions, the flotation machine type, the requirements of sludge management and dewatering systems.

3.2.2 Automation and control of jigging

In the ČSM coal preparation plant, the ŠKODA jigs are used with air distributed by turning slide valves. When we were installing the control system, we reconstructed them. To allow for multiple pulsations, we replaced the turning slide valves by disk valves controlled by membrane valves. By pulsation we mean alternatively letting the working air in and out of the jig chambers causing a vertical water flow in the jig to carry along the coal grains and separate them. A technological computer enables, apart from single, double, and triple pulsation, control of the incoming air pressure, water quantity, and the height of the bed in each field of the jig. The computer also provides automatic control of elevation. In the ČSM coal preparation plant, in 1994 – 1996, five jigs were gradually reconstructed. Double pulsation was used for them. In 1996, a team from the Department of Coal Preparation at the VŠB TU Ostrava headed by Professor J. Nováček and Associate-Professor O. Bláhová performed a comparison assessment, which, among other things, stated that the yield of the washed coal increased by up to 1.9%.

We have also automated the jigs (mostly of the OM type manufactured in Russia) in other coal preparation plants. The latest jig control system was put in operation by ATP Soukup in the Důl Darkov coal preparation plant in 2000. Here the control system is based on the modular AmiT system. The implementation consists in installing several control loops. The unit itself forms the automatic pulsation control in the jig. Several pulsation types can be selected: simple pulsation where the pulse rate per minute can be controlled or multiple pulsation with the cycle period set in seconds. In addition, the system allows for

further control loops: automatic control of heavy product raising, automatic bed elevation, air pressure control in jig field collectors, and bottom water flow control.

In 2001, ATP Soukup is planning to deal with the jig control in the Důl Paskov coal preparation plant.

3.2.3 Heavy-liquid separation control

The original hydrostatic method for measuring the specific mass of the washing suspension (that is, controlling the density by adding water or float-controlled fresh suspension) was replaced by our system of measuring the quantity of ferromagnetic heavy medium in the suspension. This method was implemented in all OKD coal preparation plants except the Jan Karel plant. The output is an electric signal that, after gauging, represents the value of the specific mass of the suspension and is the basic control quantity – adding fresh washing suspension or water. This also includes control of levels in circulation pits of the first and second separating sections and in the pit for the diluted liquid. The set values of the separation section are maintained with a tolerance of $0,01$ kg/dm^3 and they are controlled and recorded by the control system like in flotation.

3.2.4 Flocculant dosage control in sludge thickeners

To increase the efficiency of flotation gangue sedimentation in the DORR thickeners and to improve the reversible washing water quality we have developed and installed a device to measure the concentration (turbidity) of the reversible washing water with an adjustable measurement range of 0–2 and 0–6 g/l. This made it possible to install a mechanism controlling the dosage of flocculant into the flotation gangue brought to the Dorr thickener.
The same device is used to measure the filtered water concentration after the hyper baric Andritz filters. This is used to check on the HBF for correct function (particularly ruptures of filtering cloths are detected).

3.3 Automated control and information system

All the sensors and local controls of technological nodes are connected to the coal preparation plant control system. An **Alpha controlling computer** forms the heart of the system running with the real-time VMS operating system (older systems built in the early nineties are run on PDP 11 computers). To implement these systems we used the hardware and software platform developed by Digital (Compaq since 1998) since this platform is very suitable for use in real-time processing because of its performance, robustness, considerable stability and safety.

All the input and output devices are connected to the controlling computer via serial interfaces.

Data are collected from the sensors in data concentrators. These are devices with ix86 or Pentium processors and the MS-DOS operating system (plus a real-time RTX extension) equipped with cards for sensor connection. To each of these concentrators, 400 to 600 sensors can be connected. The data concentrators also store programs controlling the technological nodes (such as jigs or the flotation) and contain control loops. A concentrator communicates with its parent system using the ADLP10 protocol over a serial data line with the RS-232 interface.

The output device serves as user interface. The basic output unit is a so-called terminal group. This is a set of devices whose minimum configuration comprises: an operation terminal, an alarm terminal, printer, and a graphic station. Currently, up to 16 terminal groups can be connected to a system configured accordingly.

Alphanumeric VT525 terminals are used. The terminals offer the operators a set of applications to display the current process status, to adjust some of the parameters of technological nodes (such as the control constants), or even to intervene in the control. The alarm terminals are used to display alarms – messages informing on technological limits being exceeded. The monitored device and the values of the monitored limits are set by the operator. The system solution using a terminal network has definitely proved to be successful in the coal preparation plants in comparison with the alternative solution using a distributed PC network (by its lower purchasing cost, trouble free operation, easier maintenance, and resistance to undesired action by the operator).

Under he term graphic station we understand a PC equipped with the Promotic visualisation software developed by Microsys Ostrava with applications of a visualising technology. A graphic station displays technological diagrams and allows the plotting of selected quantities.

3.4 System of coal preparation plant control

Our system is characterised by **modularity** and **multi-layer feature**. Thanks to its modularity the system allows easy modifications of its scope and behaviour and new modules being added to meet the customer's demands (modules for maintenance, machine down-times, etc.). The layers separate the functional blocks of the system, which communicate with each other via a data interface.

From the user's point of view, the "data collection", "alarm", and "presentation" layers are important. The functions of other layers are hidden to the user and thus there is no point in describing them here.

The data collection layer processes the data supplied by sensors through data concentrators. The system accesses each sensor separately, which means that each sensor uses its own methods of conversion, averaging, and linking to other sensors. Each value is verified in relation both to the sensor's basic properties and to other technologically similar sensors. This ensures that other layers can work with verified information on the technological process.

The alarm layer allows monitoring, assessment, and reporting of non-standard situations occurring during a technological process. It is also important that only messages reporting on really significant deviations should be produced by the system. For this reason, several mechanisms have been introduced to filter out short-term alarms or those not important in terms of system control. The triggered alarms are displayed, acknowledged, and archived. Alarms are enabled and disabled at two levels. At the production management, this is entirely at a controller's discretion; alarms enabled at the top management level are mandatory for controllers and cannot be disabled (these are alarms concerning serious quality and technology deviations).

From a user's point of view, system presentation is most important. It takes place in terminal

groups. On terminals, the alphanumeric format is used while graphic stations use the graphic format. A graphic station provides the user with a number of technological views from global ones to views of machine groups. The user may interactively select the sensors to be viewed or the calculated values to be plotted on the screen.

Time is another presentation aspect. Using this aspect, the output listings may be classified as operational and summarizing. An operational listing provides information on the momentary technological process status. Summarizing listings give an overview of longer time periods and typically provide production summaries over one shift, day or month.

Apart from these listings, the system also offers to the users listings that can be used to adjust a technological process, such as setting the flotation control parameters.

At present, ATP Soukup operates control systems in coal preparation plants of the **Důl Lazy** and **Důl Darkov** mines (a control system was also operated in the coal preparation plant of the Důl František mine. However, this preparation plant was closed down in 1998 as part of a government reduction scheme). In 2001, a control system will be put into operation in the coal preparation plant of the Důl ČSM coalmine (as a replacement of the existing PDP 11/83 based system).

4. Sales control systems

The sales control system developed by ATP Soukup is a database-oriented system with a Microsoft SQL server with Windows NT as its core. The three systems we have implemented in OKD a.s. coal preparation plants are operated on computers with Alpha processors. At the time the system was designed (1995/96), the configurations with these processors were somewhat more expensive as compared with the solutions using the Intel platform but their performance, reliability, and stability was considerably higher. At present, the use of the Alpha processor based platform is no longer of any advantage the Intel platform meeting all the requirements.

We put three sales control systems into operation, namely in the **Důl ČSM** (1996), **Důl Lazy** (1996), and **Důl Darkov** (1999) coal preparation plants. The system clients – standard PC's with Windows 95 - are equipped with applications installed as needed. Let us mention at least the most important of these applications: daily overviews by ranges of products, customers, real-time loading, monthly loading statistic, marketing quality parameters, real-time train loading, monthly reports on marketing quality, statistics of loaded product quality measurements with the Wilpo quick analyser, daily loading schedule, preparation and printing of bills of freight and journey reports for export and inland, decade and monthly fuel quality reports, arbitration recording, summary of loaded wagons, statistic of loaded lorries, etc.

As mentioned above, some configurations work in real time – due to the nature of the controlled system, responses of several tens of seconds are satisfactory, which means that the system as a whole is not extremely overloaded. According to the information we have obtained, targeted interventions in the coal preparation process may be carried out to eventually optimize the sales and shipping.

The management of a coal preparation plant can also use tools to generate new, currently

required listings (the Microsoft Office package) analysing and summarising processes. In this way, the system can be adapted and extended without interventions by software specialists.

An independent part of the system is the connection to organisations that, even though external, are an integral part of shipping and marketing. Without these organisations, the system would be incomplete. Along this line, the most advanced system is installed in the Důl ČSM coal preparation plant, which is connected to OKD Doprava (transport company) and to the shipping department of the BOS a.s. marketing company. OKD Doprava provides the system with important information on empty wagons available for loading. The BOS shipping department is in charge of the contractual part of marketing and wagon shipment. Thus it provides data for the actual work in the coal preparation plant. It supplies the preparation plant with daily loading programmes (orders), used to control the loading. The sales and shipping system, in turn, feeds the preparation plant with data used to print bills of freight and journey reports for shipped wagons. The system installed in the Důl ČSM coal preparation plant also sends shipping information to Metalimex a.s. – seated in Prague, a coal exporting company.

In 2000 we started work on further development of these systems aiming to establish links to the central sales control system at BOS (in Ostrava). The central system uses the SAP R/3 system. The linking of the systems will improve the coordination and optimization of marketing activities in OKD.

5. Benefits from system installation

The benefits the system installation will bring should be assessed from several angles. The simplest evaluation uses the direct economy of profit brought by installing the automated control of technological nodes. For example, in the Důl ČSM coal preparation plant, the introduction of flotation control clearly raised the quality of the flotation concentrate and resulted in considerable economy in the consumption of flotation agents. With the automation of separation in the ČSM jigs, an increase of 1.9 % in the washed product yield could be clearly observed (based on an analysis made by VŠB TU Ostrava). Thanks to these two items alone, the investment in the entire control system returned in less than a year.

Another benefit is the permanent monitoring of maintaining technological discipline. The permanent inspection of a technological process allows the controllers to detect any deviation from the technological regulations, to analyse them and remove the cause.

The coal preparation plant control system significantly extends the scope of unbiased information on the operation and enables real-time monitoring of the process. It makes it possible to record the progress of each technological process. It guards the exceeding of watched limit values. It processes control and statistical data.

By presenting the results of monitoring technological processes in coal preparation plants and sales departments, the company management receive sufficient data to be used for production analyses, quality assurance of the manufactured products and their marketing. Thus they are in possession of a powerful tool for production optimization and quality assurance meeting the ISO 9000 standards.