Creation of a control automation system on the example of the coal processing plant

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Abstract. Creation of automation system for control over technological processes of an preparation plant is considered. The functional structure, technical structure, hardware system solutions based on Hewlett-Packard, Omron and MOXA components, basic software based on Wonderware System Platform 2017 package are considered in detail. The selected hardware tools have reduced system development effort and increased system usability and efficiency.

1. Introduction
Coal mine No. 12 (Kiselevsk, Kemerovo Oblast) is the oldest existing coal mining enterprise in Russia. Since 1917, it has been developing the subsoil area of the south-eastern part of the Kiselevsk coal deposit. From the coal enterprise was born a working village, which became the city of Kiselevsk.

In 2013, it was decided to develop the area of open-pit mining and to stop the above-category hazardous underground mining. The annual production level of K and T grades of coal is over 730 thousand tons.

Currently, a new modern preparation plant (PP) of “Mine No. 12” is under construction with a production capacity of 4 million tonnes of raw coal per year.

Among the main design and technological solutions of PP “Mine No. 12” one can note [1-2]:
- application of coal preparation methods, which give low energy intensity of production;
- optimal combination of domestic and foreign equipment with its integration into an efficient and highly reliable structure;
- flexibility of the technological scheme providing the possibility to change the structure of the object, the choice and realization of rational schemes and modes of the enrichment process;
- ecological compatibility and safety of all production, reached by application of the closed warehouses of raw coals and concentrates, the closed cycle of turnover of water, exception of traditional processes of drying of a concentrate;
- high level of automation of units, technological processes and in general the whole production using modern software and hardware.
The main goal of creating a system of automatic control (ACS) of the “Mine No. 12” – improvement of management efficiency of the technological complex and, consequently, improvement of technical and economic indicators of its functioning:

- reduction of specific production costs and increase in the yield of a suitable product;
- improving the quality of marketable products.

The objective is achieved in the following areas:

1) automation of information and control functions when solving tasks:
   - operative formation and analysis of information about changes in operation modes and condition of technological processes, units and equipment, electric and thermal energy consumption;
   - operatively coordinated correction of tasks for the mode parameters of technological processes;
   - operational implementation of control solutions and regulation of technological parameters;
   - control, accounting and analysis of technological and production discipline violations, management efficiency;

2) increase of reliability of the control automation system of the technological complex, efficiency and quality of control and management due to:
   - application of modern technical means, methods and algorithms of automatic control, analysis, diagnostics and control of technological processes and equipment;
   - complex and detailed display of information about the state of equipment and units, changes in technological parameters, actions of operational personnel in the system;
   - use of modern microprocessor controllers as a technical base at the lower level of the system, having high reliability, long operating time for failure, easy replacement of failed elements, extension of technical structure, modification of mathematical and software;
   - minimizing the number of unreliable electromechanical devices in local logic control and management systems of individual mechanisms and units.

2. Enlarged functional structure

The enlarged functional structure of the united automated technological complex of PP “Mine No. 12” is shown in figure 1. It consists of the following main systems:

1) the system of automation of control of loading and warehouse complex (ACS LWC) of PP “Mine No. 12”, including:
   - system for centralised data collection, processing and storage;
   - the system of engineering support of the LWC;
   - the automated system of operative dispatching control (ASODC) of a boiler-house complex;
   - ASODC loading complex;
   - ASODC pumping station;
   - ACS by boiler room complex, loading complex, coal storage;
   - local ACS of treatment facilities, pumping station;

2) control automation system for the beneficiation plant of “Mine No. 12”, including:
   - system for centralized collection, processing and storage of PP information;
   - production process control system;
   - system of engineering support of preparation plant
   - ASODC by technological complex of preparation plant (ASODC TC PP);
   - ACS storage of raw coal;
   - ACS by coal reception;
   - ACS by the main building of the PP;
   - ACS by the drying and furnace department;
   - ACS wagon dumpster.
Figure 1. Scheme of the functional structure of the combined automated industrial complex of PP Mine No. 12.

Integration of the existing ACS LWC and the projected ACS TC PP and creation of the united automated technological complex of the PP is provided by [3-5]:

- creation of a single information space in the system of centralized collection, processing and storage of information and in the automated system of operative dispatching control of the factory technological complex, the general discipline of data visualization and dispatching control;
- inclusion of control algorithms for coordination of technological modes and mutual equipment interlocking at the interface points of the existing loading and storage complex and the projected technological complex of the processing plant into the structure of the mathematical support of the ACS;
- partial use of hardware-software means of ACS LWC for realization of functional ACS TC PP.

3. Extended technical structure
The schematic of the enlarged technical structure of ACS PP “Mine No. 12” is shown in figure 2. Hardware implementation of the system is based on microprocessor-based programmable controllers, servers, disk array, personal computers, HMI-terminals, laptop, printer, switches and interface converters.

This set of technical means is sufficient to perform all automated functions. The technical means of the ACS PP are equipped with standard interfaces and exchange protocols, which allows for their seamless integration with other systems if necessary.

4. Hardware implementation of ACS top level systems PP
Hardware realization of systems of top level ACS PP is executed on the basis of servers, personal computers, a laptop, the printer, a disk file and switches of corporation Hewlett-Packard (USA), HMI-terminals of corporation Omron (Japan) and the network equipment of company MOXA (Taiwan).
The system of centralized data collection, processing and storage consists of two physical virtualization servers (primary and backup) and a disk array. Each virtualization server is based on the HP Proliant DL360G10 server with two XEON processors. Each server houses five virtual machines:

- IAS1: Wonderware Application Server primary object server, Device Integration Server primary I/O server, Kepware OPC Server;
- IAS2: Wonderware Application Server standby object server, Device Integration Server standby I/O server, Kepware OPC Server;
- IDE: Wonderware Development Studio development server, Dream Report reporting software;
- History: Historian Server;
- GR: licensing server, Galaxy Repository.

For the initial configuration of the PP servers the HP LCD 8500 console and HPE 0 x 1 x 8 G3 KVM switch are used.

The disk array is implemented on the basis of HP MSA 1050 with 600 Gb hard drives combined into a RAID-array to exclude information loss in case of failure of one of the drives. The main function of the HP MSA 1050 drive array is to increase system resilience and flexibility.

During normal system operation, virtual servers (IAS1, IAS2, IDE, History, GR) are migrated to the disk array. The provider of data for workstations is the main virtualization server Srv1. In case of failure of the main virtualization server, its virtual machines are automatically migrated to the backup server Srv2, which is in the "hot" reserve. This option of redundancy provides increased fault tolerance of the system and data safety, eliminating the loss of production information.

The control system of industrial processes is realized in the form of WKSs of specialists of engineering and technical and planning economic services of the factory.

WKSs of specialists are implemented on the basis of personal computers HP ProDesk 400 G5 SFF with 27" LCD-monitors (5 WKSs in total) and are located in the AB, in the premises of the corresponding specialists of engineering, technical and planning and economic services of the factory.
The system of engineering support of PP is intended for instrumental support of existing and design of additional information and software for controllers, servers, workstations, HMI- terminals of operators in the process of search of rational technological regulations, adjustment, further development and modernization of ACS PP. The system is represented by a stationary engineer's workstation (personal computer), implemented on the basis of HP ProDesk 600 G4 with 32" LCD monitor and mobile engineer's workstation (laptop), implemented on the basis of HP 15-bs017ur with 15.6" LCD screen. The engineer's workstations are located in the AB, in the control system room.

The automated system of operative dispatching control of the PP technological complex is represented by the control desk of the PP dispatcher with two WKSs of the PP dispatcher (main and reserve) and the network printer, the control desk of the drying and furnace department operator with the WKS of the DFD operator, and also five control panels CP10-CP14 of operators.

Dispatcher's desk of PP is implemented on the basis of the standard desk of the firm “ConsErgo” of the 200 series, on which two WKSs of dispatcher's PP (main and reserve) and network printer are located, and also the equipment for operative dispatching control and management is mounted. Dispatcher's desk of PP is located in the room of the AB dispatcher's office.

Each of the dispatcher's workstations is based on a personal computer HP ProDesk 600 G4 with two 32" LCD monitors. As usual, the supplier of real-time production data for the dispatcher's workstations is the virtual server IAS1 of the physical server of the PP. In case of failure of the virtual server IAS1, there is an automatic switchover to the standby server IAS2, which is in the "hot" reserve, which eliminates downtime and loss of production information. Switching of dispatching workstations to the standby virtual server takes place without pauses or delays. In case of failure of the main workstation of the PP dispatcher, a backup server is activated, which is in the "hot" reserve.

The workshop operator's console is based on the Rittal console and is located in the drying operator's room. The workshop operator's console is equipped with a workshop operator's workstation, which is based on a HP ProDesk 600 G4 PC with two 32" LCD monitors, as well as control and monitoring equipment.

Operator control panels are based on Omron HMI terminals with touch screens. Operator control panels for heavy-duty machines, floatation machines and rock bunkers are based on Omron's 15" NS HMI terminal series, which are installed in Rittal’s hermetically sealed operator desks and placed at the respective operator workplaces.

Operator control panel for cake unloading is based on an Omron HMI NS-series 10" HMI terminal installed in an airtight Rittal control unit at the respective operator's workstation.

5. Hardware implementation of low level ACS systems PP
Hardware realization of systems of the bottom level ACS PP is executed on the basis of controllers of series CJ2 of corporation Omron (Japan) and the network equipment of company MOXA (Taiwan).

Functionality and technical characteristics of these controllers fully correspond to the tasks of their application in ACS PP.

Lower level systems are built using controllers connected to each other via an information network via Ethernet/IP, with the transition to fiber optic cable for connecting the controllers located in other locations.

For connection of external devices and autonomous systems with RS485 interface (Modbus protocol) corresponding Omron communication modules are used.

The exchange of information between controllers, with devices connected via RS485 to the corresponding Omron controller communication modules, with service stations, with PP servers, with operator’s HMI-terminals is carried out via the information network via Ethernet and Ethernet/IP protocols.

When the CJ2 controller runs out of I/O channels, an NX-based remote I/O basket is added and connected to the controller via Ethernet/IP using the corresponding NX-EIC202 communication module.
6. Basic software
“Mine No. 12” was selected as the basic software for ACS:
- Wonderware System Platform package by Wonderware, a structural unit of Schneider Electric Corporation (France);
- VMware vSphere virtualization system (USA);
- modular OPS server Kepware OPC Server by Kepware (USA);
- Dream Report reporting software by Ocean Data Systems (Israel);
- CX-One software for configuration, configuration, programming and debugging of Omron automation equipment (Japan).

The basic ACS PP software is modular, as open as possible and includes the following software products:
- I/O tools (Device Integration Server, Kepware OPC Server);
- system platform (Wonderware System Platform);
- virtualization system (VMware vSphere);
- Wonderware Historian Server (VMware vSphere); archiving and storage tools;
- Data analysis and reporting software (Wonderware Historian Client, Dream Report);
- Production data collection and processing software (Wonderware Application Server);
- data visualization software (Wonderware Supervisory Client);
- system development and maintenance software (Wonderware Development Studio, CX-One).

There are three modes of control of the technological scheme in the control system of PF “Mine No. 12”:
- automatic control (the “Automat” mode is the main mode in which all information and control functions are automatically implemented);
- remote control (modes “Distance”, “Individual Distance”), in which the system automatically implements all information functions, but the control of each unit (on/off) is performed by the dispatcher;
- local control (modes “Local”, “Individual Local” – auxiliary, adjustment), in which the system automatically implements all information functions, and the control of each individual item of equipment is carried out by commands from local control posts.

Selection of the control mode of the technological complex “Automat”, “Distance”, “Local” is carried out with the help of the control panel of the dispatcher PP.

7. Conclusion
Designing of ACS of PP “Mine No. 12” is carried out in a very short time – 5-6 months, with a standard time of design of 9-12 months. It became possible, at the expense of parallel, simultaneous performance of some design works, application of typical design decisions and use of environments of the automated designing.

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