

A New Approach to Monitoring in the Advanced Dispatching System for Coal Mines

J. Wojciechowski

Research and Development Centre for Electrical Engineering and Automation in Mining EMAG, Katowice, Poland

ABSTRACT: Monitoring and supervision systems based on binary signals (machine operation/standstill), which are currently in common use in Polish coal mines, are insufficient for management needs. Machine diagnostics and facility management require continuous checking of the load parameters of longwall complexes, mining machines, haulage lines and the power supply conditions of machines. The visualization of the state of an object as complex as a mine must be uniform, fast and synchronized, forming the basis for selective, easy data access. For almost 30 years, the EMAG Centre has been developing and supplying dispatching systems to coal mines. This paper deals with how the development of computer-based systems proceed. The function and features of the new dispatching system SD2000 are described. Coal mine monitoring levels and applied web, Internet and intranet technology are presented.

1 INTRODUCTION

Efforts in the Polish coal industry to withstand competition from foreign coal are focusing on the areas of safety, reliability, profitability and environmental protection of mines (Mironowicz & Wasilewski, 2000). This means that mines must be provided with modern techno-organizational solutions in order to enable improvements in output.

This can be achieved by:

- extending the effective operating time of machines and equipment,
- increasing time between overhauls,
- minimizing production stoppages resulting from safety hazards.

However, this situation requires a new approach to supervision problems at mines. The demands of operations management in the control area of a modern coal mine can be met only by sophisticated equipment and control systems. The range of duties of the main dispatcher of the mine extends from human safety through high availability and long service life of machines to high efficiency and rapid deployment of reserve capacity. Comprehensive monitoring of the mining complexes and haulage lines together with diagnostics and early warning of pre-failure states are essential.

2 DEVELOPMENT OF DISPATCHING SYSTEMS AT EMAG CENTRE

The early 1970s marked the beginning of computer-aided dispatching systems in Polish mines. Based on original constructions - the minicomputer MKJ-25 (Gacek & Wojciechowski, 1976) - the first dispatching systems were implemented at two mines. Processing limits made it necessary to replace the MKJ-25 with proven hardware and system software. In the late seventies, a clone of the minicomputer series HP2100 was created, application software was developed, and mines were provided with a system called SMC-3. Operational experience, developed software and access to domestic medium-scale integrated elements at the beginning of the eighties resulted in the production of the industrial minicomputer PRS-4 by the EMAG Centre (Mokrosz et al., 1982). Successful construction (up to 1988, 150 sets were produced - the majority installed at mines in Poland, Romania and China) became the hardware base for modular dispatching systems offered by the EMAG Centre to mines.

The basic modules of this system were:

- HADES - monitoring of process run and output balance.
- SAK - evaluation of bounce hazards by seismoacoustic methods.
- SYLOK - location of tremors and estimation of their energy.

- CMC 1/2 - digital methane monitoring outstation.

The next stage in the evolution of dispatching systems at the EMAO Centre was the development of the MICROHADES and DTS modules. The DTS module made it possible to present technological data on semi-graphical color television screens, creating a Dynamic Synoptic Table. The DTS software was introduced to the PC platform by a group of former workers of EMAG, and the ZEFIR system (Dec & Gajoch, 1999) was implemented in mines starting from 1992.

3 PROJECT GUIDELINES FOR SD2000

Although the ZEFIR system was at first accepted by users, soon there was a need for further development. However, the decision to retain compatibility with preceding versions (SMC-3 -> PRS-4 -> PC; DOS -> Windows; flat binary, file data structures) prevented effective technological changes. In Poland in the nineties, coal mines became part of the economy where the notion of efficiency and profit became a normal economic term. Dispatching systems had to become instruments contributing to cost reduction in coal mining and machine operation. The concentration of mining and considerable reduction in employment required the development of system functionality on the mine surface as well as underground. The system had to become open, a component module of the future system type MRP, ERP or SAP for mines. This was a new approach to the problem of dispatching systems at the EMAG Centre. The first attempt to replace the DTS function by large-format projection took place in 1998 (PTS-1, Poppe & Zymelka, 1998). In 1999, EMAG proceeded to develop a completely new dispatching system, named SD2000 (Wojciechowski, 1999). The supervision of processes and the mine safety state requires systems of continuous operation based on developed structures of analog data acquisition which provide information about the parameters of equipment operation and processes. Decision making on the basis of a huge data stream is beyond the capacity of a mine dispatcher. Thus, it was necessary to create a hierarchical supervision structure at particular levels, with the separation and suitable assignment of control functions to a special mine division.

A modern monitoring, control and management system for mines cannot consider the problems of individual machines, devices and processes separately, but must put them together in complex, correlated structures presented on the mine spacing chart. This concerns not only the ventilation system but also the structures of transport, power supply,

power shutdown, advance rate and the location of the cutter-loader at the longwall, etc. This was the starting point of the project.

In the project, the following assumptions were accepted:

- to make diagnostics of longwall complexes as thorough as possible,
- to relieve the chief dispatcher of the observation of process parameters by transferring part of his duty to a suitable division of the mine,
- to offer the chief dispatcher concentrated, easily comprehensible information,
- to assist the chief dispatcher in critical situations and in the control of miners working underground,
- to provide the accounting, planning and quality inspection departments with tools for analysis and simulation,
- to provide high-level supervision staff with tools for quality inspection,
- to eliminate duplication of work connected with updating maps, plans and diagrams in paper and electronic forms by including a planning department to direct the service of the system,
- to reduce the service and maintenance costs of the system,
- to use the latest computer technology,
- to present the monitoring results according to a hierarchical scenario.

For the computer part of the SD2000, the following assumptions were accepted:

- an open, distributed system,
- PC and Windows platform,
- standard communication protocols,
- modern, effective database,
- intrinsically safe system for digital field transmission,
- dedicated industrial network (Ethernet) on the surface, operating in conjunction with the LAN in the mine.

4 IMPLEMENTATION ISSUES

A hard coal mine, as an object of monitoring, presents a complex spacing structure. In the conventional systems of control and supervision, monitoring is applied at two levels - local and global. At the mine, this corresponds to the level of technological centre supervision and the dispatcher's level observing all processes according to the accepted scenario. To date, dispatcher system support has used two scenarios - territorial and technological. The first includes monitoring of all equipment and sensors in one place, e.g., getting region; in the other, monitoring comprises a group of devices combined in technological line, e.g., main haulage with surge tanks. So far, no hierarchical

scenario has been realized. On the one hand, it features a highly concentrated information overview of the state and run of all-mine processes in one compact area at the same time; on the other hand, It presents, in a remarkably simple way, detailed information on the operation, standstill and failure of all equipment. The realization of such a scenario required the development of technology and price reduction in an efficient engineering process within the hardware, software and database mechanisms.

The idea of presenting the mine structure and technological and safety state with the use of the methods applied in the programs of the geographical information system and management facility GIS/CAD FM lay in:

- the use of real maps and schemes used every day by a mine to create images of mine spatial structure on monitors or large-screen displays,
- the assignment of graphical schemes of particular technologies to successive image layers, e.g.:
 - alarm broadcasting communication line,
 - telephone line,
 - power network,
 - degassing pipelines,
 - air pipelines,
 - fire-fighting pipelines,
 - fresh and used air current path (ventilation system),
 - escape routes,
 - location of technological lines,
 - location of fans,
 - location of air-stopping,
 - location of signaling-telephone sets,
- animation of change in the color/shape/size of a graphical object, representing a sensor change of the measured parameter,
- signaling of fire/gas/bounce/water hazards in the region by change of color in the area background,
- connection of the sensors on the map with a database containing current and archival measuring values and description.

All these, accomplished by intelligent software of the MMI environment, made the dispatcher's work easier, enabling:

- the manipulation of layers in any combination of overlapped images of beds and process maps,
- the selection, zoom and storing of maps and installation fragments selected in a very easy way by using the favorite option,
- fast search and location of objects on maps through knowledge of their exact or approximate names,
- personalizing of MMI (Man Machines Interface).

The benefits of such an approach are:

- the use of only a single set of technical documentation (digital) by all mine divisions,

- simultaneous mapping of changes in surveying geological and technological description at all mine workstations,
- updating of documents at specialist divisions (communication, electrical engineering, ventilation, methane monitoring, etc.) with the background of an up-to-date mine plan,
- forecasting of hazards by the chief dispatcher on the basis of the association of mining run effects on changes in safety parameters in remote mine regions,
- direction of the service specialists nearest to the damaged machine or device to repair it according to the optimal route,
- safe withdrawal of miners from dangerous areas.

In the SD2000 system, a series of new solutions within the domains of organization, technology and structure was applied. In this system, a new idea was used, different from the present philosophy of mine management. By departing from a central dispatching system, the distributed structure of dedicated subsystems to particular mine services was applied. The system has a hierarchical structure (Fig. 1) within the range of monitoring, presentation and visualization methods.

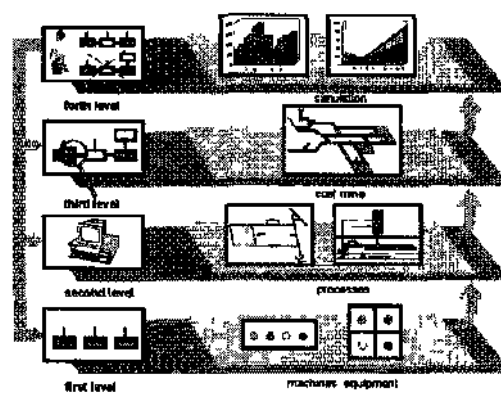


Figure 1 Monitoring structure

The operators and service personnel control the operating status of the equipment and machines on LCD graphic panels of local substations directly at the mine workings (level I). The subsystems (level II) of the mine divisions (power, machinery, communication, methane monitoring and ventilation) collect the detailed data. The specialists in these divisions become the active users of the supervising system and not only the consumers of processed information. At the chief dispatcher's stand (level III), necessary concentrated, easily comprehensible information is offered by all the subsystems. The dispatcher makes use of integrated

data in a synoptic table and supervises the technological parameters and safety state of the mine. Fast, reliable decision making is ensured in all operating situations. Operating on the WINDOWS NT platform, the SD2000 system distinguishes itself by intelligent graphic access to information. Internet technology enables remote diagnostics of machines, service and updating of the software components even from outside the mine site (level IV).

The SD2000 software is based on three-layer architecture, which is characterized by a vertical applications partition into logical useful layers. Each makes up an integrated part, which can communicate with elements on the next levels by network mechanisms. The first layer (of presentation) is used to communicate with a user. For the users (i.e., high-level supervising staff, planning departments, remote users) who make use of the informative function of the system, a WEB viewer, e.g., Internet Explorer, constitutes the program of this layer. This layer cooperates with the application server. The function of this server is to process all data according to defined rules, i.e., with application logic. Here, the data analysis and the creation of report contents and trend diagrams is performed. The database server is at the lowest layer and it receives data from the measuring systems. The three-layer architecture improves the safety of the system because both the application server and database are placed in a separate safe segment of the network. This architecture also reduces installation costs as it does not require a lot of licenses (which are not cheap) for the users of database servers. One license per application server is enough. The customers using common data can only obtain a connection with the last one.

The SD2000 database has a compound structure. Local process databases at network nodes depict a monitored process in real time and over a longer period depending on the process type. The database of one node constitutes a source of data for others. The global relational database uses structured query language used by the applications programs to collect and analyze the data. Using its advanced mechanisms, this database ensures adequate efficiency, safety and access to information. It also enables access to data through the Internet or intranet. Data are collected from all the nodes, i.e., local dispatching substations, in a homogeneous base. The database performs the role of a data warehouse, separating the executive information sphere from that of decision information.

In the SD2000 system, the Internet is widely used for:

- building a centre for remote diagnostics, maintenance and conservation of dispatching systems at mines by EMAG,
- providing the management staff of the coal mine

with dispatching information in indoor, delegation, holiday or operating conditions (Fig. 2),

- making information from the dispatching system available to supervising staff working in the mine LAN.

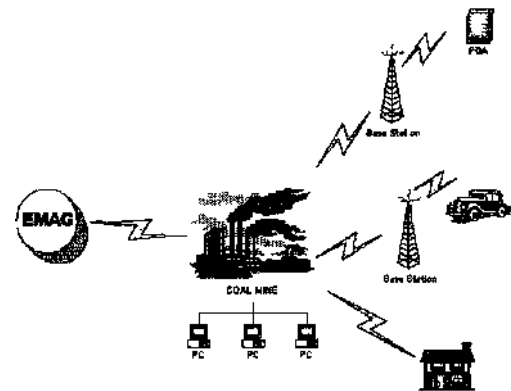


Figure 2. A coal mine as a WEB vertical portal.

An advantage of using standard HTML/XML for the presentation of data from the database server is that the data are available on any computer connected to the network and equipped with a WWW viewer. The use of server-client architecture (in this case, a WWW viewer) dramatically reduces the costs of installation and maintenance of many stands where production data should be accessible. Only the computer, which operates as a server, must be a real computing power unit. The "customer" computers can be common all-purpose stations without special hardware requirements.

5 FEATURES OF SD2000

The SD2000 system has network architecture and it is composed of intelligent nodes distributed all over the mine. The nodes are connected by an industrial network at the process level, and by the LAN at the dispatcher's and management levels. The nodes can operate autonomously, which makes development and configuration easier in accordance with mine requirements.

Acquisition and access to information from the nodes are obtained in a form of network variables.

The features of the man-machine interface MMI in the SD2000 system are:

- user-friendly action, based on a cursor manipulator and standard keyboard and right profiles,
- simple and easy action for familiarization of service, based on readable icons, virtual keys,

contextual menus and an on-line assistance system,

- assistance in work by additional windows warning of alarms and a system of profiles varying the form of presentation depending on requirements,
- clarity of information directed to operation of the mining-haulage process and analysis of disturbances on the multi-monitor dispatcher's control desk.

By placing the cursor on a graphical object representing a selected sensor and pushing the right mouse button, the user gains access to a wide range of data (Fig. 3), such as the type, serial number and producer of equipment, information about overhauls carried out and the appointed times of periodical surveys, and current measuring data in graphical and numerical form where the breaks of criteria are signaling.

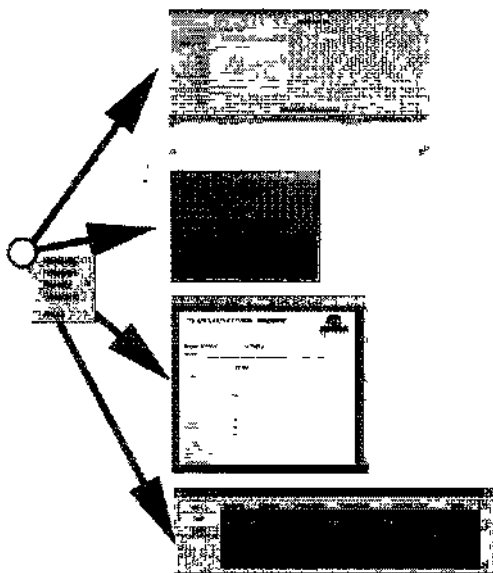


Figure 3 Sensor as information carrier

The multi-screening technique enables the service of all connected operator monitors by one keyboard/mouse (Fig. 4). A graphic video wall presents an image of the whole mine state, as well as scaled-up fragments, allowing the dispatcher to analyze particular technological lines, haulage elements and dangerous areas with full measuring-monitoring information just as on the dispatch office monitors, but with a considerably larger active surface of visualization. This makes it possible to include a great number of graphic and measuring-monitoring data without affecting the clarity and

readability of the image, thanks to the high resolution of the optical system (1600*1200). The graphic video wall, built from easy-to-configure projection modules placed one next to the other, creates a one-piece screen with the size depending on the needs of the mine and its financial resources.

Visualization of the mining and haulage processes as well as the safety state is based on several categories of images:

- those showing the arrangement of machines, equipment and sensors in the background of a real spatial picture of the mine by means of digital maps of beds and levels,
- simplified diagrams of installations, technology or networks,
- look-up images, presenting several sizes in a compact simple form on screen simultaneously,
- group images, presenting comprehensively die conditions of selected technologies, processes and safety,
- trends, presenting runs on a time basis,
- images previewing reports sent to the printer
- those showing message lines of failure, hazards, commands and event histories with sorting of information on events under different criteria, e.g., priorities, technological areas, types of events.

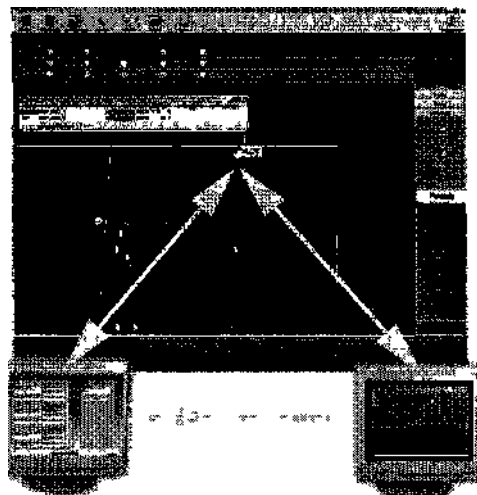


Figure 4 Multi-screening technique in the SD2000 system

6 COMPUTER PART OF THE SYSTEM

From the IT point of view, the SD2000 system forms the farm of servers working in their own network domain. Data from the technological server, alarm and communication server, haulage server and hazard monitoring and ventilation control server are

transferred to the database server of a central system by use of ADO technology. The central system consists of a set of servers, workstations and supporting equipment.

The software of the central system has a modular structure. Of the many modules, there are modules of data collection and for building the base of real-time data, the protection module responsible for the archive, replication and recovery functions, modules generating diagrams and reports, and the editing module.

Each change in the value of any measured variable is marked with a time stamp and according to the value, it is sent to tables for the needs of corresponding modules. On the image displayed on the graphic video wall (Fig. 5), the module of technology and safety presentation animates, on the basis of measured values, the graphical objects which represent machines and equipment in the background of mine maps. These values fill the alarm and measurement tables and produce messages for the dispatcher. Diagram modules take care of the proper graphical presentation of these values. The report module generates a list of events in the system at a certain time. The layer structure of the displayed images makes it possible to assign groups of layers comprising a given subject area to particular technologies, systems and networks. The appropriate rights of access to particular layers allow the distribution of the editing module between mine departments that update their sphere of duty, without the possibility of them changing elements in which they should not interfere.

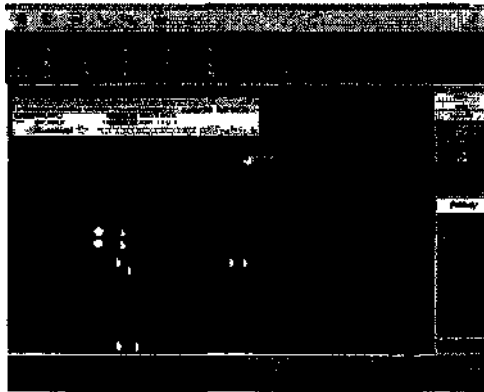


Figure 5. Synoptic module.

The editing module enables the updating in a remarkably simple way of maps, diagrams and objects. In editing, it is possible to make use of a library of graphic elements representing the mine equipment.

The SP2000 system ensures connection and data exchange with other databases. Due to genuine technological solutions, the extremely fast connections, stores and access to the relational database are achieved.

By application of the ODBC protocol, the SD2000 system can cooperate with well-known databases such as Sybase, Oracle or Informix. Integration with the mine computer network, by using an intranet vertical portal for information coming from the database server, is very important. Data generated in the form of diagrams, tables and reports can be seen by any Internet viewer - without additional software at the customer's side. Active X controls built in to the portal allow graphic presentation of various diagrams on a WWW page.

The histograms and linear diagrams are accessible in current or historical mode. In addition to diagrams showing the state of operation of machines and equipment, alarms are displayed with their history of occurrence.

The application software works only on the server, so there is no need to install programs in individual computers in the network or manage it at the place where these data are received. The changes in application are refreshed on workstations immediately after connection to the server. The distributed system maintains its remote outstations by itself. This is the "zero administration" feature of the SD2000.

7 CONCLUSIONS

The aim of the development work which has been carried out by the EMAG Centre over the last 25 years has been effective and efficient control of the production process run and continuous monitoring of safety conditions. This work has resulted in a series of solutions within the range of communication, alarm signaling, control and supervision of machines and equipment and mine safety control.

As one of these solutions, the SD2000 dispatching system enables the integration of the spheres mentioned above, providing advanced monitoring and dispatcher support, data presentation and visualization and use of modem software technologies. Thus, it has emerged as a new reference point for a new generation of dispatching systems for mines in the new millennium.

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