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HADES: Security and Monitoring System for Selected Technological Processes in Polish Underground Mining

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Abstract:

A mine cannot operate without environmental monitoring systems and basic mining machinery and equipment. In individual mines, these systems work in various configurations. Current information from these systems is visualized in the mine dispatch rooms. This article presents the basic structure of the visualization system, focusing on those most commonly used in our mines. It highlights that the diversity of monitoring systems used does not favor their unification and integration, aimed at providing the entrepreneur with essential data necessary for making crucial decisions related not only to the functioning of individual facilities within a company but, most importantly, the entire enterprise. The article introduces a new proprietary HADES visualization system program used in JSW SA mines. This program, named after the first microprocessor-based dispatching system implemented in Polish mines several decades ago, enables the entrepreneur to make key decisions regarding the operation of the entire coal company and its individual facilities.

Keywords: visualization systems in underground mines, monitoring of mining machinery and equipment

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1. Introduction

Geological and mining law, along with its implementing acts [1, 2], obligates the entrepreneur to monitor both environmental hazards and the technological processes of the mining facility. This requirement involves the necessity to monitor the operational status of essential mining machines and equipment used in the mine. Monitoring systems in the mine are not limited to observing selected areas using cameras but primarily involve cyclical measurements of many technical parameters of machines and equipment used in the workings, and presenting these results on monitors at selected observation points.

The data collected by monitoring systems in mine dispatch rooms are used not only for the diagnostics of machines and equipment but, above all, for the analysis and proper organization of the work of individual technological processes in the mine.

Different monitoring scenarios can be implemented in the dispatching system [3], the most important of which are:

- Technological: This scenario involves the control of a selected group of technologically interconnected devices.
- Territorial: Characterized by the supervision of various devices located in one area of the mine (e.g., a longwall face or heading).
- Hierarchical: A synthetic monitoring and evaluation of the state of many different processes that determine production or safety conditions throughout the entire mine.

2. Materials and Methods

2.1. General structure of the monitoring system in the mine

The general structure of the mine's dispatch monitoring system is shown in Fig. 1. [4].

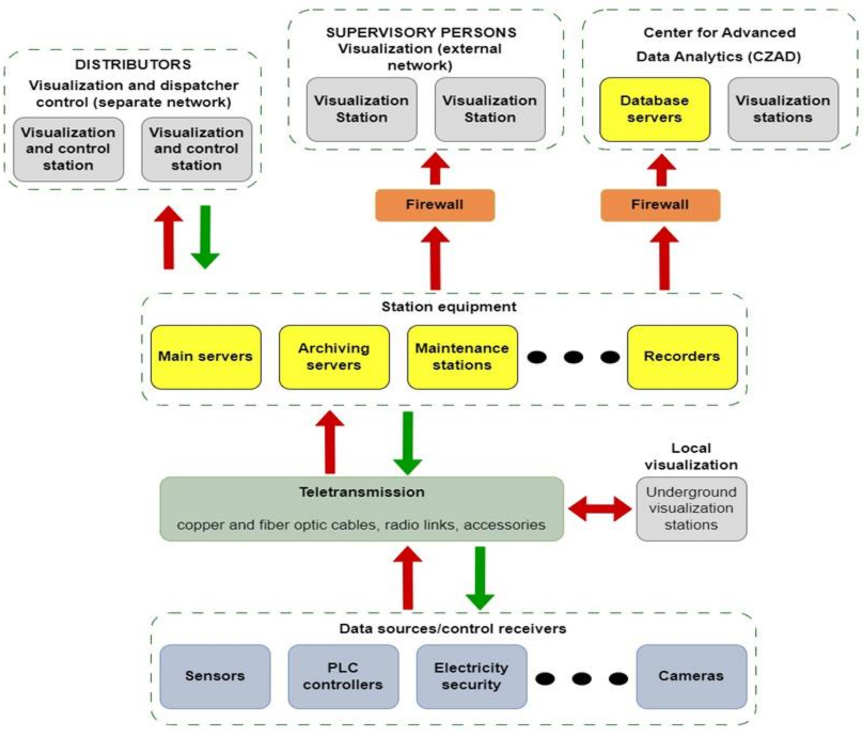

Fig. 1. Block diagram of dispatcher monitoring systems
[source: own study]

In the mine's dispatch system, three main layers can be distinguished:

- Data sources: PLC controllers, local stations, protections in electrical devices, cameras, and other end devices (sensors, signalling and executive devices).
- Telecommunication networks: Copper and fiber optic networks along with accompanying devices.
- Station devices: Such as central units, servers, control stations, visualization stations, maintenance stations, video recorders, etc.

In certain situations, it is possible to control underground devices (e.g., switching on and off switches in the power network). Data from the servers is also transmitted to visualization stations in the mine's general network (the so-called external network) using appropriate measures for protection against cyberattacks.

3. Computerized systems for monitoring technological processes operated in JSW SA mines

Initially, due to technical capabilities, so-called binary state visualization systems for mine technological processes were constructed. In 1980, at the Moszczenica mine, based on the PRS-4 industrial microcomputer, the so-called Modular Dispatch System type MSD-80 was launched. One of its modules was a system for controlling production parameters and selected safety parameters, commonly known as HADES [5].

It was intended for:

- Binary control of the operation of machines and equipment forming technological sequences (longwall faces, main haulage).
- Balancing of the extracted material (at loading points and shafts).
- Control of the operation of machines and equipment not linked in technological sequences, such as development faces, pumps, compressors, scales, fans, seals, water levels, water pressure in fire pipelines, etc.

By the late 1980s, this system was replaced by the upgraded MSD-90 system, which featured a new production control module called microHADES (μHADES) [6]. It allowed the processing of signals from approximately 2000 binary and counter inputs, serving as an intermediary for their visualization.

The advancement in computer technologies also enabled the development of so-called dynamic synoptic tables (DTS-1), which used semi-graphic monitors (typically with a resolution of 25 lines of 80 characters each). DTS-1 was implemented from the late 1980s. Information about the technological process in the mine was most commonly displayed on screens of six 23-inch graphic monitors.

In the 1990s, the ZEFIR system became widespread. It was the first dispatch visualization system utilizing IBM PC-class personal computers running under the DOS operating system. This system, after numerous technical and software modifications, is still in operation in most mines today, setting many informal standards for the functioning of computerized visualization systems in mines [7].

As the development of computer-based monitoring systems for machines and equipment progressed, manufacturers began offering their own (proprietary) software for visualizing individual technological processes. This made the integration of monitoring systems more difficult. Developers of universal visualization tool software had to coordinate data exchange protocols with the manufacturers of transmission systems.

An analysis of the current state revealed that several different visualization systems are used concurrently in every Polish underground mine. Some are used by the main dispatcher, others by the methane monitoring dispatcher, and still others in energy-mechanical dispatch centers or transport control centers. Table 1 presents examples of visualization systems used in Polish mines [7, 8].

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Table 1. Examples of monitoring, control and visualization systems used in Polish mines

System	Company Name	Description
DEMKop	SOMAR Katowice	This system is used for visualization and generation of reports from the data which is obtained from machines and devices. This is dedicated to the control rooms of hard coal mines. SMok is used as a hardware solutions
e-kopalnia	FAMUR Katowice	This is a mining machinery supervision system that consists of a set of ICT solutions, hardware, and measuring tools. The main elements of this system are machine control devices (e.g. FAMAC: MRS, OPTI, DMP), IT systems (like servers, LS local station, MPC I computer), hardware, and software diagnostic systems
EMAC	ENERGO TEST	A system which is used for the industrial facilities and this is dedicated to power grids. it cooperates with PLC controllers of these devices and protections equipped with an open communication protocol
eSPiM CSBiRE	WINUEL Wrocław	eSPiM is used for the Electronic energy metering and billing system and CSBiRE is used for the Central Energy Balancing and Settlement System. These systems are used for the visualization, reporting, and management of electricity consumption; used in KGHM.
MonSteer-D	Tranz-Tel Kobiór	FOD-900 is a Dispatch supervision system that is designed to gather and transmit information from the underground mine. This is also used for the plant operations and safety dispatcher
SAURON	RedNT (RNT) Cieszyn	The SAURON visualization system which is used for Control, Traffic Automation and Supervision. This system is used for communication with the IEDs of mining equipment and dedicated software applications (which is known as modules) such as: Pumping Stations, 6 kV Network, Haulage, Walls, Faces, Skips, Loading, Air Conditioning, ZPMW
SD-2000	EMAG	This is a Dispatching visualization system - Utility software.
SmartWall	Elgór+ Hansen Chorzów	Integrated system which is used for control, visualization and monitoring of mining machines and equipment. The system has proprietary hardware components (e.g. flameproof computer EH-O/06, control panel EH-O/01, separator EH-O/03) and software components for visualization and control (e.g. KESSA-ATON, EH-WallView, EH-MineView)
SP3	HASO Tychy	This is the Abbreviation of the words: "Industrial process presentation system" Utility software
SWµP	HASO Tychy	The Computer support system work as methanometry dispatcher; Utility software
SYNDIS (RV)	MIKRONIKA Poznań	This is Supervision, Consulting and Control System used for Industrial Installations. This system is used for monitoring and controlling the operation of the mine's power system; is used in KGHM
THOR	SEVITEL Katowice	This is a Dispatch system which is used for visualization, monitoring, archiving, generating reports and control. Utility software
WIZAS	Becker Warkop	Visualization system which is used for longwall machines with dedicated BECKER controllers
WIZCON Supervisor	Wizcon	This is a Dispatch system which consist of WIZCON visualization module; popular SCADA software that allows you to manage processes using a web browser
ZEFIR ZEFIR/NT	PRUNELLA Katowice	This is the first dispatcher visualization system used in many mines. This is used for the first time in 1991 in the Andalusia mine

4. Genesis of the HADES system implementation

In the European Union (EU), coking coal mined by JSW SA is classified as a critical raw material because it is essential for steel production. Poland supplies only 25% of the total demand for coking coal in the EU. Considering this, a few years ago, the management of JSW SA prepared a new business strategy that significantly incorporates the ongoing digital transformation in the mines towards the development of the so-called intelligent mine JSW 4.0. One of the tasks of this transformation was the establishment of a specialized IT unit at the enterprise level, IT Systems JSW SA, whose primary tasks included the creation of the Advanced Data Analytics Center (Polish abbreviated name: CZAD JSW 4.0) and, in the area of monitoring, the Central Technological Data Server (Polish abbreviated name: CSDT). CZAD was a fundamental element of a comprehensive plan to increase production management efficiency, standardize the broad area of automation, telecommunication, and IT systems supporting JSW SA's production processes [9].

Data on the operation of key machines and equipment, describing the course of production processes, are dispersed across the various technological systems of the mines. Integration of data from different areas, considering the functionality and performance of dedicated SCADA systems in the mining industry (Table 1), is limited and has not yet been conducted at the enterprise level.

Addressing this issue, in 2018, the JSW SA capital group began implementing the "Standardization of Data and SCADA Systems" project. As part of this project, JSW ITS Systems launched a new proprietary SCADA system named HADES, based on the Asix Evo platform by Askom. The name of the new SCADA system refers to the history and launch of the first microcomputer production parameter control system in the MSD-80 modular dispatch system at the Moszczenica mine over 40 years ago.

For better cooperation with the individual units of the JSW SA Group (Polish abbreviated name: GK) in the various mines (facilities), automation departments (Polish abbreviated name: EDA) were established independently of the communication departments (Polish abbreviated name: EDŁ).

The establishment of new, multi-kilometer fiber optic networks at both the enterprise level (GK JSW SA) and in the workings of individual mines enabled the real-time transmission of a large amount of data to CZAD and the central CSDT server in IT Systems JSW SA [10].

The expansion of CSDT with new reporting methods, the use of artificial intelligence in expanding the knowledge base about the course of mining operations, and the utilization of the PI System (*The PI System is a solution for managing very large amounts of data generated in an industrial environment; it is a tool that collects, archives, manages, and analyzes vast amounts of sensor data. It provides online distribution of this data to users and applications that need it at any given moment*) in HADES allows the creation of specific reports for the company's management and key personnel. These reports, in the form of dashboards (*A dashboard is a specific type of report where the most important information and indicators related to the company's objectives are presented in a visual format. This information is displayed on a single screen (large-format panel*), contain essential production data and selected economic indicators of the entire enterprise or specific technological sequences in individual facilities, all displayed on a single screen.

5. Construction and modules of the HADES Visualization System

The HADES system includes [11]:

A virtual machine used as an application server with Asix software and Microsoft SQL Server installed. A virtual machine used as a terminal server with Asix software installed, equipped with a Remote Desktop Services (RDS) license.

User (and administrator) workstations, i.e., computer stations connected to the network infrastructure, providing access to the HADES system via the Internet Explorer web browser or the RemoteApp service.

The architecture of the HADES system is shown in Fig. 2.

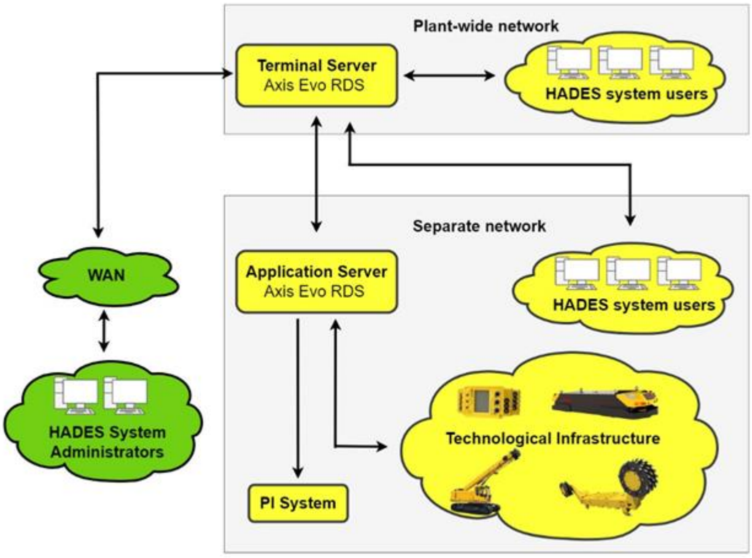

Fig. 2. Architecture of the HADES system
[source: 11]

The HADES system, developed for the needs of JSW SA mining facilities, performs the following functions:

- Acquisition of measurement data from other devices and monitoring systems operating in various JSW SA mines (Table 1).
- Visualization and control of selected technological processes.
- Alarm notifications about dangerous events, data archiving, and analysis of archived data, including reporting.
- Data transmission to MES, ERP systems, and business analysis tools.
- Data sharing with MS Office suite (MS Excel).

The HADES system has a modular structure, allowing for the successive connection of additional devices or entire installations, visualization of their operation, and control of devices and processes. The modules of this system developed so far are usually named after the primary service performed by the module:

- Visualization and control of switches and transformers.
- Control of 6 kV electrical substations.
- Central reactive power compensation system.
- Energy media measurement and billing module.
- Methane balance. Monitoring of the underground methane drainage network.
- Visualization and control of methane drainage stations.
- Media monitoring. Visualization and control of pumping stations.
- Visualization and control of reduction and filtration stations.
- Visualization and control of shaft heaters.
- Visualization of central air conditioning.
- Visualization of the operation of main ventilation fans.
- Monitoring of nitrogen generators.
- Scales and analyzers.
- Supervisory system for ZPMW.
- Visualization of longwall complexes.

Network communication is required to acquire data from devices located in individual mining facilities, which are the sources of measurements, for further processing, archiving, and making process

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data available for visualization and control. Control of automation actuators is possible via serial communication or through Ethernet networks using protocols implemented in the HADES system.

Data acquisition from devices is performed by software installed on the application server. Communication is carried out through the LAN using industrial automation protocols, such as OPC DA or UA, Modbus TCP/IP, S7 Communication, or Profinet, as well as other native protocols available in the HADES system. For industrial automation protocols based on TCP/IP, the plant network or JSW WAN networks are used. Data acquisition from end devices in the case of serial communication is conducted via media converters or converters of the appropriate protocols.

Data exchange between user workstations and the application server is carried out indirectly through the RDS terminal server using various protocols (e.g., HTTPS, Asix Network, RDP) and ports (e.g., ports 443 (*Port 443 is a virtual endpoint through which all data transmissions are sent and received. It is communicated via the transport layer protocol TCP, which helps in directing network traffic to the endpoint*), 6000 (*Port 6000 can use a defined protocol for communication depending on the application; it is a set of formalized rules that govern how data is transmitted over the network to ensure the communication is most efficient*), etc.). Data flow between user workstations in the general plant network is filtered by a firewall. The HADES system has the capability to transmit data to the PI System in CZAD for further process data analysis. Depending on the required exchange protocol, the application server configuration provides process data to the PI System via the OPC UA or Modbus TCP/IP protocol.

Using the HADES system requires user authentication (confirmation of identity by providing a password associated with an account) and access to appropriate resources and the ability to perform certain operations requires authorization, which is the verification of the authenticated user's permissions. Authorization is related to assigning the user an appropriate role. The following roles are defined in the system [11]:

- Observer: Ability to view application screens.
- Operator: Ability to view application screens, alarms, and blocks, and change descriptions.
- Local Administrator: Ability to view application screens, control devices, clear alarms and blocks, change descriptions, and edit users and their permissions.
- Administrator: Ability to view application screens, control devices, clear alarms and blocks, change descriptions, edit users and their permissions, edit visualization screens, variable databases, and add additional devices.

In the HADES system, backups of servers are performed daily, weekly, and monthly. Daily backups are executed cyclically during nighttime hours and are retained for a period of two weeks. Weekly backups are performed on weekends and are retained for a period of one month. Monthly backups are performed on the first weekend of the month and are retained for a period of three months.

6. Example visualization screens of the HADES System

As mentioned in the previous chapter, the HADES visualization system can activate many monitoring modules for selected technological processes. These modules are also available in the SCADA systems currently operated in the mines (Table 1). In the plant dispatch rooms, longwall and development faces, belt conveyors, and shaft operations are most commonly monitored (in binary systems: working/stopped, open/closed, etc.). Methane monitoring dispatchers monitor gasometry systems, fans, and seals. In the energy-mechanical dispatch rooms, 6 kV power substations and selected electrical parameters of key machines and equipment responsible for material extraction are monitored. Many publications have presented selected screens from these modules, for example, from the ZEFIR, THOR, SAURON SmartWall systems [8, 11].

Since all JSW SA mines are highly methane-prone, the creators of the Hermes visualization system have implemented four modules related to this hazard in addition to the aforementioned modules. These are the modules: methane balance, monitoring of the underground methane drainage network, visualization and control of methane drainage stations, and the energy media measurement and billing module.

Methane drainage systems are operated in JSW SA mines. JSW supplies (sells) this methane to the Jastrzębie Energy Company (SEJ SA). Visualization and mutual settlements between the seller and the buyer are carried out using the HADES system.

Figure 3 [11] shows an example screen fragment from the Methane Balance module in the HADES system.

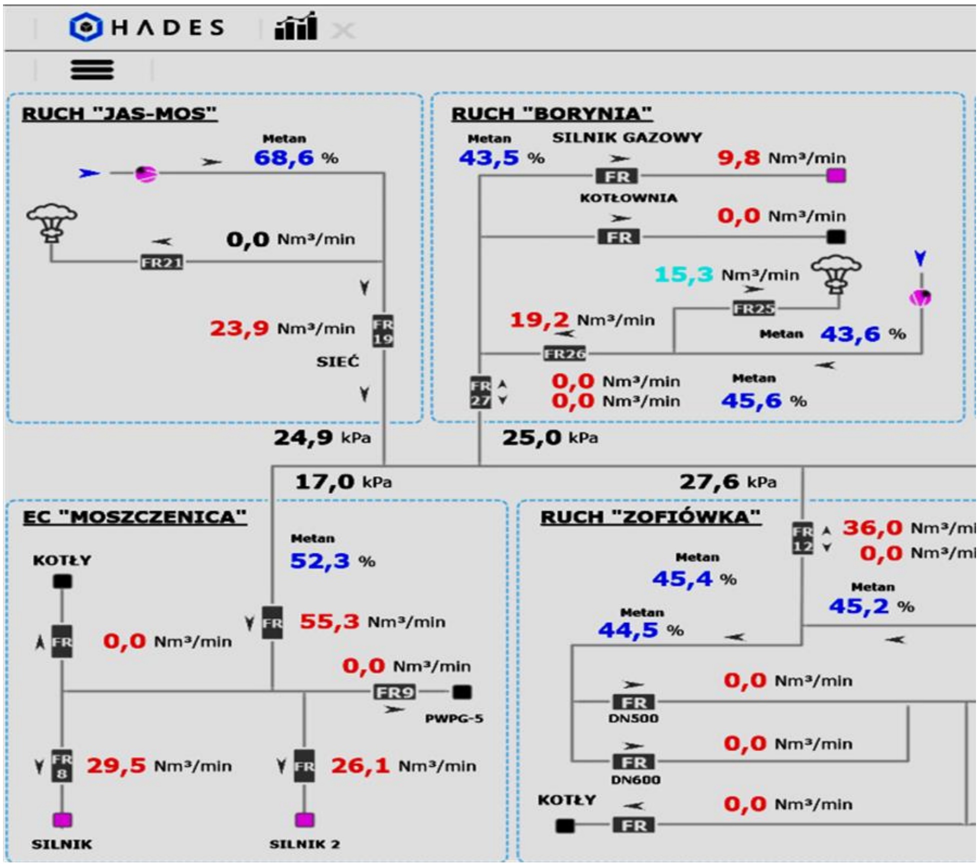

Fig. 3. Screen fragment of the gas network from the Methane Balance module in the HADES system [source: own study]

The visualization screen shows normalized flows, gas concentrations, and pressures at the measurement points of the methane drainage network. JSW SA mines have also initiated a project involving the construction of a measurement system for the underground main methane drainage networks using sensors and the CST-40 teletransmission system by HASO. For this application, the Methane Drainage visualization module was launched in the HADES system. In each JSW mine, points were selected in the underground main methane drainage networks where measurement systems should be installed. A measurement point included, among other things, a differential pressure transmitter, a methane meter adapted to measure methane concentration in the pipeline, and a pressure and temperature transmitter. Figure 4 shows a screen fragment from the Methane Drainage module for the Szczygłowice movement [11].

The screen shows values of normalized flow, methane content, pressure, and temperature at the individual measurement points of the underground methane drainage network. All JSW mines are covered by such a measurement system.

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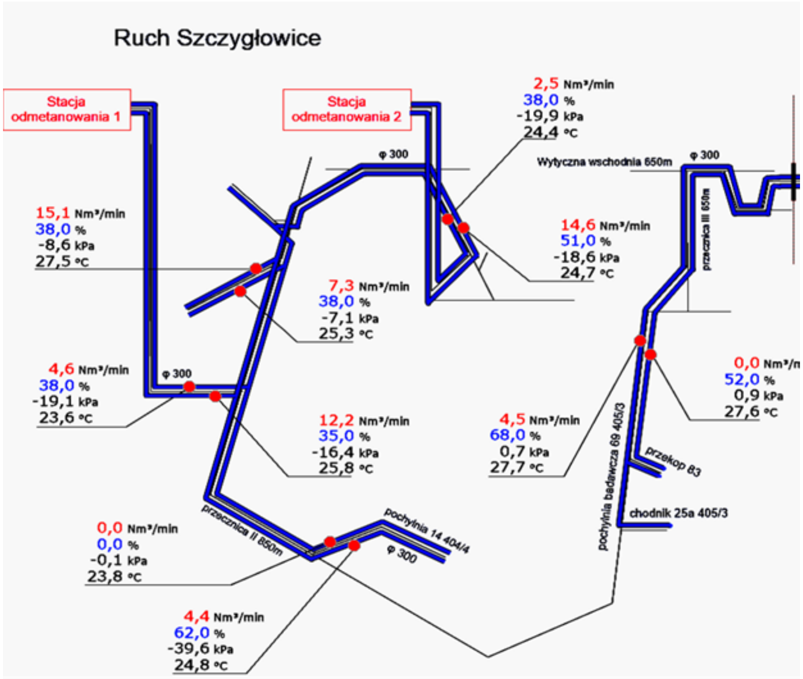

Fig. 4. Example screen fragment from the Methane Drainage module for the underground part of the Szczygłowice movement
[source: own study]

7. Conclusions

Increasing productivity in a mine can be achieved in several ways. In addition to costly replacements of existing technical equipment with new ones, one of the cheapest ways to achieve this goal is:

- increasing the effective working time of electrical machinery and equipment used in the mining plant,
- minimization of downtime, time wasted on uncontrolled failures of machines and equipment and shortening of interoperational activities (e.g. machine spacers).

These objectives can be achieved by introducing modern monitoring and visualization systems for technological processes in mines, particularly for essential mining machines and equipment. Unforeseen breakdowns should not occur in mines. Therefore, great emphasis should be placed on the continuous monitoring of electrical equipment, primarily for the early detection of irregularities in their operation and the proper preparation of planned maintenance.

The HADES system not only supports the dispatching of production processes but also aids the management in making key decisions at the level of the JSW SA Management Board.

Coal mines are considered "operators of essential services" and therefore must comply with the requirements of the National Cybersecurity System Act [12]. Ensuring cybersecurity in IT/OT networks is crucial due to the necessity of continuous operation of the mine's communication, alarm, and gasometry systems. This task is carried out by the specialized unit of the company, IT Systems JSW SA, which integrates and standardizes the teleinformatics systems operating in individual mining facilities.

The teleinformatics systems integrated into the HADES visualization system belong to the OT (Operational Technology) area, which includes both hardware and software designed for monitoring and/or controlling physical variables using executive devices in technological processes.

OT systems are most often integrated with the IT (Information Technology) area, which is essential for the operational (business) management of the mining enterprise, as these are the methods and means of operation related to information processing [9].

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