https://doi.org/10.7494/miag.2022.4.552.21

GRZEGORZ WĄS
ADAM KLUSKA
MAREK SOBOLOWSKI
MARCIN GARBACZ
MARCIN PAŁKA
MAREK WOJTAS

Underground Water Monitoring and Visualisation System at the Piast-Ziemowit Hard Coal Mine, Ziemowit Operation

The paper presents a monitoring system for the pipeline network at Piast-Ziemowit Hard Coal Mine, Ziemowit Operation, which was implemented in February 2023. The system covers monitoring of both fire system pipelines and pipelines of the dewatering and drinking water systems. The Ziemowit Operation is self-sufficient in terms of water consumption both for technological and domestic purposes. Precise monitoring of pipelines allows to maintain installation parameters at a level sufficient for technological and mine fire safety purposes. The system also allows for the detection of emergency conditions, monitoring of water levels in storage reservoirs, while in terms of hydrogeology it is used for water balancing. Flowmeters installed at the pumps allow the actual measurement of pump performance, determine their efficiency, and thus allow diagnostics to anticipate future failures and take preventive measures. Visualisation of the performance of the system is available from a web browser and enables convenient and intuitive configuration to suit the user's current needs related to making changes to the system.
The visualisation application has extensive functionality for current viewing and analysis of historical events and diagnostics of emergency conditions.

Key words: *monitoring, mine water, dewatering, visualisation*

1. INTRODUCTION

Global phenomena occurring in recent years, such as the pandemic, have popularized the concept of digitalization. Services related to digital transformation and the Internet of Things, previously known within the community dealing with Industry 4.0, have suddenly become items of everyday use. Many of us have personally experienced remote work or remote teaching. This digitalization process was rapid, but nonetheless rather superficial.

On the other hand, the international environment, the war in Ukraine, and the energy crisis are all factors that have led us to seek to intensify the extraction of our own energy resources in Poland.

There is also a third factor affecting the condition described – increasingly stringent environmental requirements are causing the mining industry to pay close attention not only to how much coal we extract, but also to what we extract along with that coal from underground areas. What has attracted exceptional interest recently is water, pumped from underground workings and used in mining plants, as well as the impact of water coming from mine dewatering on the biota of streams and rivers.

Mines such as the Piast-Ziemowit Hard Coal Mine, Ziemowit Operation due to the possession of underground water intakes with fresh water parameters, are able to be self-sufficient in terms of domestic, technological and fire water, and may even supply water to third-party customers. However, in order to, on the one hand, properly conduct the technological process, ensure the continuity of water supply for both fire and technological purposes, and on the other hand, in order to economically manage the resources held, it is necessary to know the condition of the pipelines, the amounts of water flowing in the individual pipelines, as well as have information on emergency conditions.

In addition to an extensive network of fire system pipelines, the mine operates a dewatering system that is important for operations and safety, consisting of a network of dewatering system pipelines together with main, auxiliary, and local pumping stations with capacities sufficient to protect the underground workings from flooding. Ongoing assessment of the technical condition of an extensive dewatering system without the use of supporting systems, increases the response time of technical services in case of emergency conditions, which significantly affects the cost of operation. This was confirmed by the conclusions drawn from the operation of SOMAR's first SMoK-2 surveillance system deployed to, among other things, inspect and monitor the technological parameters of the mine's network of fire protection system pipelines and water flows in the mine's dewatering system pipelines. They also highlighted the need to expand the system and cover all the most important sections of the mine where dewatering system pipelines were installed [1].

This is where room for a more active introduction of digitalization emerges, not only to support everyday life, but also to bring it underground. In connection with the expansion of fibre-optic networks and computer stations built into underground workings, this mainly concerns activities undertaken by mining companies such as the monitoring of various resources including water, the implementation of a software application called "Foreman's Electronic Notebook", as well as upgrades to the existing data acquisition systems, or planned implementations of the automation of longwall powered roof supports.

Within the scope of the modernization, a new Underground Water Monitoring and Visualisation System at the Piast-Ziemowit Hard Coal Mine, Ziemowit Operation, code-named SYSMON, was developed and implemented by Elsta Elektronika Sp. z o.o.

2. DESCRIPTION OF THE MONITORED OBJECT

Water plays a dual role in the technological process of mining in the operations of a mining plant. On the one hand, it is a threat, as it emerges from the rock mass in the process of excavation, as well as during the mining of the coal seam. In that case, such water must be quickly removed from the workings. For this purpose, networks of pipelines of the dewatering system are used, connecting local, branch and auxiliary pumping stations, as well as main pumping stations. On the other hand, however, water is a reliable fire extinguishing agent and must be available at every mine section where mining operations are taking place.

The Piast-Ziemowit Hard Coal Mine, Ziemowit Operation has three main dewatering pumping stations located on level I at Shaft I, level II at Shaft I and on level III (in the area of the C-1 cross-cut). Underground water from the main pumping stations is transferred to the surface via pipelines to a fresh water settling tank with a capacity of 115,000 m^3, and to two salt-water settling tanks with capacities of 290,000 m^3 and 104,000 m^3.

The main dewatering pumping station on Level I is equipped with seven OW-300/4 type pumping units, each with a nominal capacity of 11.0 m^3/min. The pumping station has two independent water gallery systems to provide for the intake of a 12-hour supply of water to the workings. Water is pumped through two pipelines of DN350 via Shaft I to the surface. The operation of a single pumping unit ensures that the daily inflow of water is pumped out in less than 20 hours. Since the water accumulated in the water galleries on Level I (200 m) is fresh water, it is used in part for fire-fighting systems on Level II (460 m) and Level III (640 m).

The main dewatering pumping station on Level II is equipped with seven pumping units, four of OW-300/8 type with a rated capacity of 11.0 m^3/min, and three of WPW-300/8 type with a rated capacity of 12.0 m^3/min. The pumping station has two independent water gallery systems to provide for the intake of a 12-hour supply of water to the workings. Water is pumped through three pipelines: in Shaft I through a DN 500 pipeline, and in Shaft II through DN 400 and DN 450 pipelines to the surface. Operation of a set consisting of two pumping units ensures that the daily inflow of water is pumped out in less than 20 hours.

The main dewatering pumping station on Level III is equipped with nine pumping units, six of OWH-200/10 type with a rated capacity of 5.2 m^3/min, and three of 25H47/10 type with a rated capacity of 8.3 m^3/min. The pumping station has two independent water gallery systems to provide for the intake of a 12-hour supply of water to the workings. Water is pumped to the surface through three DN 400 pipelines: two pipelines in Shaft I and one pipeline in Shaft II. Operation of a set consisting of three pumping units ensures that the daily inflow of water is pumped out in less than 20 hours. The pumping station is powered from the RD-III 6 kV switching station.

Additionally, the Ziemowit Operation also operates an auxiliary dewatering pumping station at Level –147 (408 m). Natural inflows are captured in two water gallery systems, for industrial water and drinking water.

Fresh industrial water is pumped to the surface via a DN400 pipeline in the W-I Shaft to the $V = 95{,}100$ m^3 settling tank (Olszyce), and further to the Ławecki Stream, the Mleczna River and the Vistula River.

Fresh drinking water is pumped to the surface via a DN400 pipeline in the W-I Shaft to the Water Treatment Plant, where it is treated for consumption for the mine's own purposes and sale to the municipality. Unused raw water as well as treated water is routed to a $V = 115{,}000$ m^3 settling tank.

The supply of the main pipeline networks of the underground workings fire protection system is carried out as follows:

– the main supply to the fire protection system is the main dewatering system – from a branch pipe of the main collecting pipe at the pumping station through a reducing valve to the fire protection network on Level I. The supply in Shaft I plays a backup role;
– to –120 Level (360 m) in the area of the auxiliary "Szewczyk" Shaft, water is supplied "from underground" from the network of fire-fighting pipelines on Level II (460 m) through a DN 150 pipeline in the "Szewczyk" Shaft;
– to Level II (460 m), water is supplied from two systems of water galleries on Level I (200 m), through the filtration plant and by a DN300 pipe to Shaft I. Then via a DN300 pipeline in Shaft I through an overflow reservoir under Level I (about 298 m from the shaft top) to Level II (460 m). The capacity of the overflow tank under Level I is $V = 15.5$ m^3, and its function is limited only to reducing the water pressure in the supply pipeline. The water level in the overflow tank is controlled by two float valves and is kept within the range of min. level 0.8 m to max. level 1.3 m. For emergency events of increased water demand, a pumping unit with a PH 150 type centrifugal pump of 5.25 m^3/min capacity is installed at the shaft bottom of Shaft I, Level I, which draws water directly from the water gallery bypassing the filtration plant and pumps it into the DN300 pipeline in Shaft I;
– to Level – 300 (580 m) in the area of the auxiliary "Szewczyk" Shaft, water is supplied from the network of fire-fighting pipelines on Level II (460 m) through an overflow tank installed on Level II at the "Szewczyk" Shaft with a capacity of $V = 2$ m^3 through a DN 150 pipeline running in the "Szewczyk" Shaft;
– to Level III (640 m), water is supplied from the network of fire-fighting pipelines on Level II (460 m) through a near-shaft overflow tank installed under Level II (about 465 m from the shaft top) via two DN 150 pipelines. The capacity of the overflow tank under Level II is $V = 105$ m^3, and its function is limited only to reducing the water pressure in the supply pipeline. The water level in the overflow tank is controlled by two float valves and is kept within the range of min. level 1.0 m to max. level 1.5 m.

The backup supply of the Ziemowit Operation fire-fighting system is provided from the surface water treatment plant tank with a capacity of $V = 2000$ m^3 via a DN 200 pipeline in Shaft W-I through a reducing valve installed on Level II (460 m) to the P-1 cross-cut on Level II. In addition, it is also possible to supply the fire-fighting system on Level II from the pressure pipeline of the main dewatering pumping station on Level II through the OS 150/5 pump with a capacity of $Q = 2.5$ m^3/min.

Currently, the Ziemowit Operation is completing the task of the construction of a fire pipeline in Shaft I from Level I to Level II. The newly constructed pipeline is intended to replace the existing fire pipeline in Shaft I. The DN 300 shaft fire-fighting pipeline will transfer water from the overflow tank located on Level I (200 m) to Level II (460 m), to a redundant pressure-reducing station. The station will be terminated with a branch collector, which will be used to distribute water at the shaft bottom to the fire protection pipelines and to supply Level III also bypassing the overflow tank located under Level II (a system of SUPRA valves will be used to supply both Level II and Level III; the goal is to eliminate all float valves in the plant, as they are highly unreliable). Figure 1 shows the described dewatering scheme employed at the Ziemowit Operation.

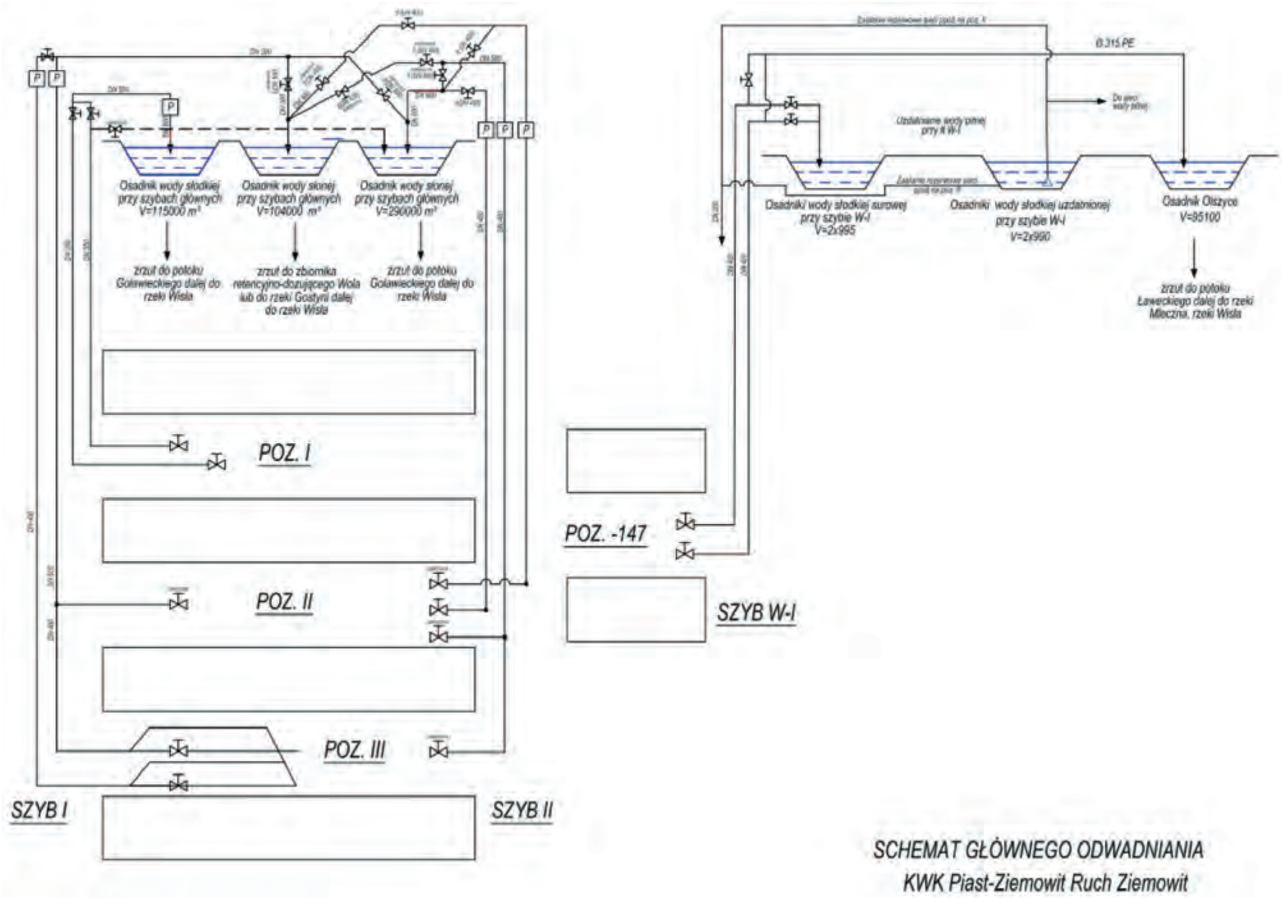


Fig. 1. Diagram of the main dewatering system at the Piast-Ziemowit Hard Coal Mine, Ziemowit Operation

In accordance with the current regulations, water inflow to mine workings in a mining plant has to be measured at least twice a year (Article 1, § 449 of the Regulation of the Minister of Energy of November 23, 2016 on detailed requirements for the operation of underground mining plants (Journal of Laws of 2017, item 1118) [2]. As a practical matter, the volume of water inflows into the mine workings is monitored on an ongoing basis due to safety of the mining operations.

3. DESIGN OF SYSMON SYSTEM

The underground water monitoring and visualisation system at the Piast-Ziemowit Hard Coal Mine, Ziemowit Operation (SYSMON) is designed in its underground part as a hierarchical structure with two concentrators (SK-01, SK-02), where each concentrator is responsible for data acquisition from its respective area (Level II, Level III). There are 13 measurement and communications cabinets (SPKs) connected to the concentrators and, in the case of the SK-01 concentrator, the two nearest measurement points are also connected. The total number of measurement points in the system is 20 dual points (volume flow and pressure) and two single points (water level measurements). The SPK cabinets come in different configurations, depending on the number of measurement points connected to a given cabinet (from 1 to 3) and the number of built-in dual displays on the cabinet front cover. In most cases, the SPK cabinets are installed in the vicinity of the measurement points, so it is possible to read the measured values of volume flow, pressure, or level locally. In four cases, due to the excessive distance to the measurement points, SP measurement cabinets were installed in the area where flowmeters and pressure sensors were fitted, allowing data to be read and sent to the SPK cabinets over the MODBUS RTU protocol. Communication between the SPK cabinets and the concentrators is carried out using SHDSL technology. Table 1 shows the specification of the node and measurement points.

Data transmission to the surface is carried out over a copper telecommunications network and fibre-optic Ethernet. In the surface part, the heart of the system is a database server, which at the same time is a webserver for the visualisation application.

Table 1

List of node points and measurement points within the monitoring system

Cabinet	Point No.	DN	PN	Location of measurement points	Measuring device
SPK-02 #01	1	DN200	PN25	level -147 – drinking water, Piast II Shaft	– flowmeter – pressure transducer
	3	DN200	PN25	level -147 – industrial water, Piast II Shaft	– flowmeter – pressure transducer
SPK-01 #02	2	DN150	PN25	level -147 – drinking water, Hołdunów Shaft	– flowmeter – pressure transducer
Concentrator SK-01#03	4	DN200	PN25	entry gallery to # I	– flowmeter – pressure transducer
	22			water level at #I	– level probe
SPK-02R #04	5	DN200	PN25	cross-cut E-1, level 600 m	– flowmeter – pressure transducer
	10	DN200	PN25	cross-cut P-1 – dewatering pipeline	– flowmeter – pressure transducer
	9	DN150	PN16	cross-cut P-1, level 200 m	– flowmeter – pressure transducer
SPK-01 #05	6	DN150	PN16	intersection of cross-cuts for wheeled traffic E-1/E2	– flowmeter – pressure transducer
SPK-01 #06	7	DN150	PN16	cross-cut E-3, level 3650 m	– flowmeter – pressure transducer
SPK-01 #07	8	DN150	PN16	intersection of P-1 and K-2 cross-cuts	– flowmeter – pressure transducer
SPK-01 #08	11	DN200	PN25	water inflow from seam 215	– flowmeter – pressure transducer
SPK-02 #09	12	DN150	PN16	#I side of empty mine cars	– flowmeter – pressure transducer
	13	DN150	PN16	#I side of loaded mine cars	– flowmeter – pressure transducer
SPK-02 #10	14	DN150	PN16	belt conveyor heading C-1	– flowmeter – pressure transducer
	15	DN150	PN16	belt conveyor heading C-4	– flowmeter – pressure transducer
SPK-01 #11	16	DN150	PN16	cross-cut to "Szewczyk" Shaft	– flowmeter – pressure transducer
SPK-01 #12	18	DN200	PN25	cross-cut for wheeled traffic C-2, level 300	– flowmeter – pressure transducer
SPK-02 #13	17	DN300	PN16	dewatering system pipeline in conveyor belt heading C-4	– flowmeter – pressure transducer
	19	DN200	PN25	dewatering system pipeline in inclined drift 950	– flowmeter – pressure transducer
SPK-00 #14	20	DN250	PN16	cross-cut for wheeled traffic C-4 in front of heading 1203	– flowmeter – pressure transducer
SPK-01 #15	21			level I – water level	– level probe
Concentrator SK-02#16	–	–	–	–	–

In the event of a power failure, the system switches to backup battery power, so that for a period of not less than 60 minutes the data can continue to be logged and transmitted to the server on the surface. Due to the fact that there are no active devices between the data concentrators and the SPK cabinets, after a power outage the transmission is carried out uninterrupted from the farthest sections of the mine. A power supply failure (and thus operation on backup power supply) is also indicated on the main synoptic screen. Also, any transmission system failures are logged and signalled in the system. A transmission failure does not cause interruptions in local data reading, so during transmission line repair works, supervision of the pipeline network is carried out by mine staff at the location where the measurement sensors are installed.

The entire system was designed, manufactured, and installed by Elsta Elektronika Sp. z o.o. in close cooperation with Ziemowit Operation engineering personnel.

4. VISUALISATION AND REPORTING

The visualisation of the SYSMON system operation is available from a web browser. The visualisation software application has extensive functionality for viewing the current state on both the system diagram and flat or 3D maps, as well as analysing historical events and diagnostics of emergency conditions. Multiple parameters can be simultaneously entered on the charts for any selected period of time, allowing to detect possible correlations between them.

From the main synoptic screen (Fig. 2), which is a diagram of the entire system, thanks to interactive features, it is possible to go directly to screens with maps of specific sections or to charts of a given parameter. On the screen below the diagram, there is a separate field for displaying ongoing messages, events, and alarms. On the synoptic screens, the pipelines of the fire, dewatering, and drinking water systems are marked with their respective colours.

On the same screen, but in a different view (Fig. 3), it is possible to obtain the total flow rate readings of the flowmeters, also split into total flows in accordance with the planned flow direction, as well as flows in the reverse direction.

The spatial map (Fig. 4) is an interactive map, allowing the user to zoom in and out of the monitored areas, as well as to switch to charts of the parameters of the indicated measurement point.

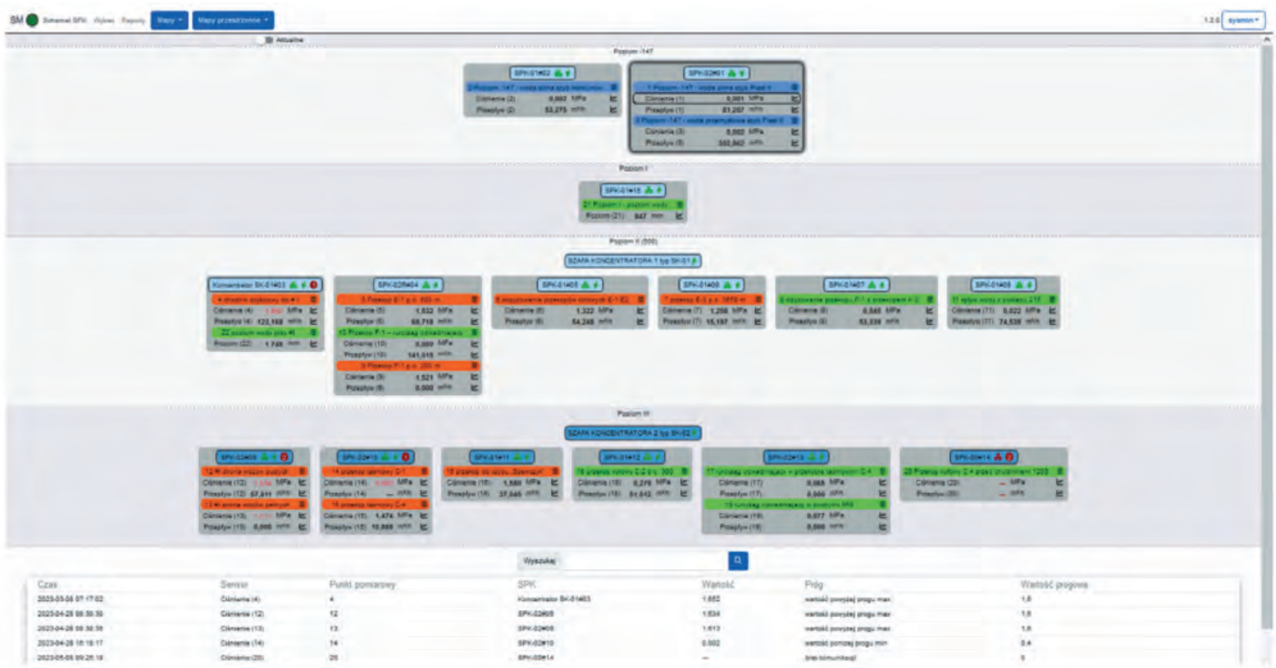


Fig. 2. View of the main synoptic screen of the SYSMON system visualisation application with current indications from the measurement devices at the Piast-Ziemowit Hard Coal Mine, Ziemowit Operation

Fig. 3. View of the main synoptic screen of the visualisation application of the SYSMON system with the total indications from the flowmeters at Piast-Ziemowit Hard Coal Mine, Ziemowit Operation

Fig. 4. Screen presenting a spatial map of the pipelines of the fire, dewatering and drinking water systems

The entire pipeline system has been divided into sections, and there is a separate detailed map for each section (Fig. 5) in the form of a synoptic screen with a presentation of the parameters measured in this particular section. Interactive elements marking individual measurement points allow the user to navigate to charts of the parameters of the selected point.

The data on the charts can be presented in several modes:

– "approximation" in the selection list stands for the averaging of values from selected data ranges – this way, with a large amount of data, a chart showing the trend of change is obtained;
– "decimation" or downsampling is the selection of a certain number of samples so that the overall image of the chart remains unchanged, thus ensuring that the chart for a large amount of data remains responsive;
– "raw data" – the chart presents all the data logged in the selected time span.

An example chart of the monitored parameters is presented in Figure 6.

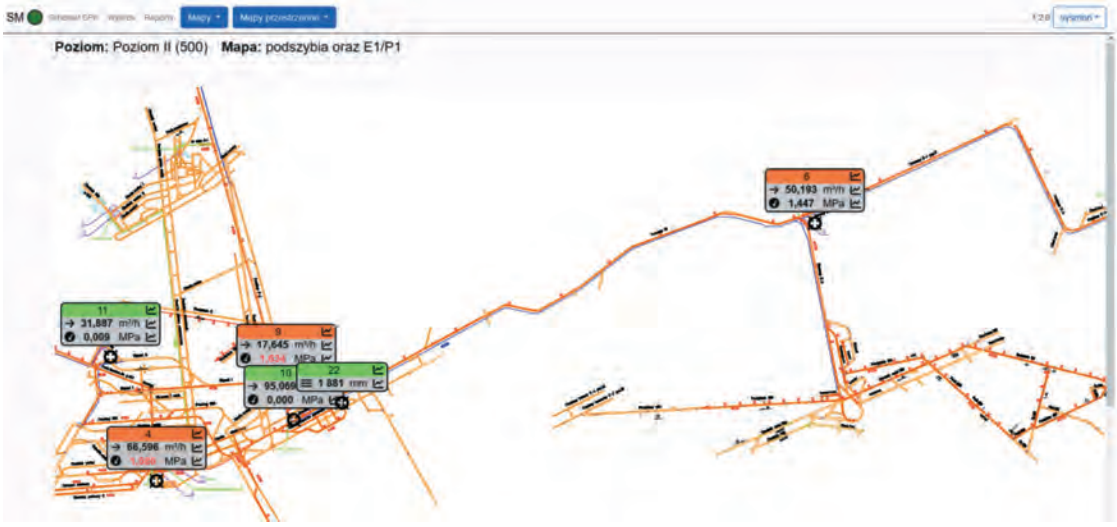


Fig. 5. Example screen showing a map of the section with current indications from the measurement devices

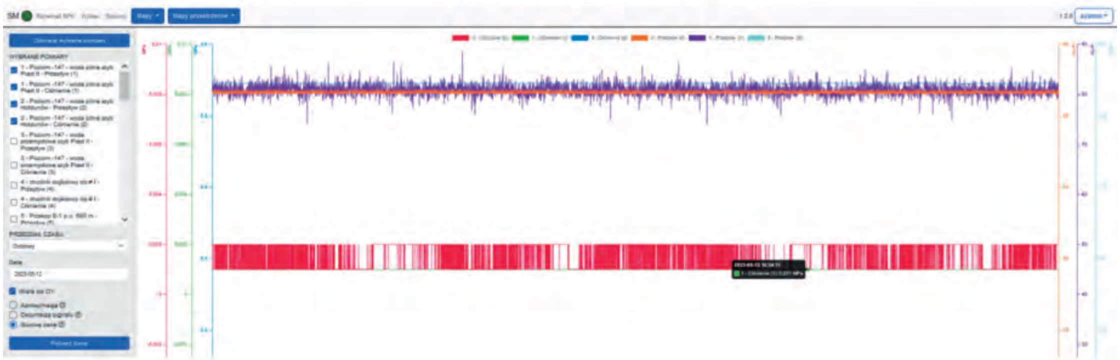
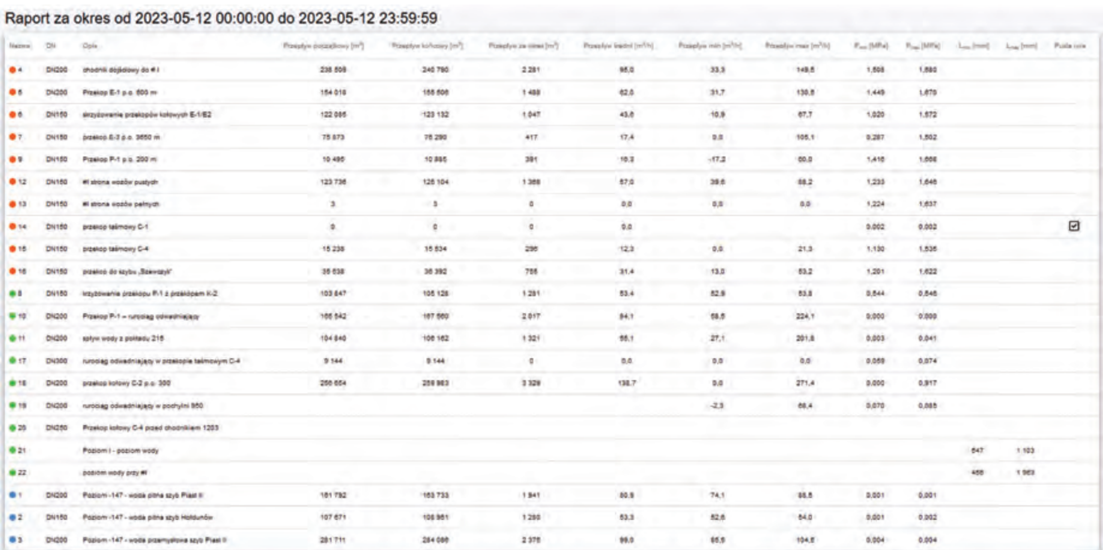


Fig. 6. Chart of selected parameters with selectable display mode

The system software allows the user to create reports for any period of time or select any of the predefined reports (daily, monthly). In the report presented on the screen (Fig. 7), the measurements for pipelines of the fire, dewatering and drinking water systems are colour-coded.

Once the report is generated as a pdf file, separate reports are created for each of the three pipeline types (Figs. 8–10).

The software application allows convenient and intuitive configuration to suit the user's current needs related to making changes to the installation.



Raport za okres od 2023-05-12 00:00:00 do 2023-05-12 23:59:59

Nazwa	DN	Opis	Przepływ początkowy [m³]	Przepływ końcowy [m³]	Przepływ za okres [m³]	Przepływ średni [m³/h]	Przepływ min [m³/h]	Przepływ max [m³/h]	P_{min} [MPa]	P_{max} [MPa]	L_{min} [mm]	L_{max} [mm]	Pusta rura
4	DN200	chodnik dojściowy do #I	238 509	240 790	2 281	95,0	33,3	149,5	1,508	1,880			
5	DN200	Przekop E-1 p.o. 600 m	154 018	155 506	1 488	62,0	31,7	130,8	1,449	1,870			
6	DN150	skrzyżowanie przekopów kołowych E-1/E2	122 085	123 132	1 047	43,6	10,9	67,7	1,020	1,572			
7	DN150	przekop E-3 p.o. 3650 m	75 873	76 290	417	17,4	0,0	105,1	0,287	1,502			
9	DN150	Przekop P-1 p.o. 200 m	10 495	10 885	391	16,3	-17,2	60,0	1,416	1,666			
12	DN150	#I strona wozów pustych	123 736	125 104	1 368	57,0	39,6	68,2	1,233	1,646			
13	DN150	#I strona wozów pełnych	3	3	0	0,0	0,0	0,0	1,224	1,637			
14	DN150	przekop taśmowy C-1	0	0	0	0,0			0,002	0,002			☑
15	DN150	przekop taśmowy C-4	15 238	15 534	296	12,3	0,0	21,3	1,130	1,536			
16	DN150	przekop do szybu „Szewczyk"	35 638	36 392	755	31,4	13,0	53,2	1,201	1,622			
8	DN150	krzyżowanie przekopu P-1 z przekopem K-2	103 847	105 128	1 281	53,4	52,9	53,8	0,844	0,846			
10	DN200	Przekop P-1 – rurociąg odwadniający	165 542	167 560	2 017	84,1	68,5	224,1	0,000	0,000			
11	DN200	spływ wody z pokładu 215	104 840	106 162	1 321	55,1	27,1	201,8	0,003	0,041			
17	DN300	rurociąg odwadniający w przekopie taśmowym C-4	9 144	9 144	0	0,0	0,0	0,0	0,069	0,074			
18	DN200	przekop kołowy C-2 p.o. 300	255 654	258 983	3 329	138,7	0,0	271,4	0,000	0,917			
19	DN200	rurociąg odwadniający w pochylni 950					-2,3	66,4	0,070	0,085			
20	DN250	Przekop kołowy C-4 przed chodnikiem 1203											
21		Poziom I - poziom wody									647	1 103	
22		poziom wody przy #I									458	1 963	
1	DN200	Poziom -147 - woda pitna szyb Piast II	161 792	163 733	1 941	80,9	74,1	85,5	0,001	0,001			
2	DN150	Poziom -147 - woda pitna szyb Hołdunów	107 671	108 951	1 280	53,3	52,6	54,0	0,001	0,002			
3	DN200	Poziom -147 - woda przemysłowa szyb Piast II	281 711	284 086	2 375	99,0	65,5	104,8	0,004	0,004			

Fig. 7. Daily summary report on the screen in the visualisation software application

KWK PIAST-ZIEMOWIT RUCH ZIEMOWIT
System monitorowania sieci rurociągów w wyrobiskach dołowych w KWK Piast-Ziemowit Ruch Ziemowit
Raport za okres od 2023-05-12 00:00:00 do 2023-05-12 23:59:59
ppoż

Nazwa	DN	Opis	Przepływ początkowy [m³]	Przepływ końcowy [m³]	Przepływ za okres [m³]	Przepływ średni [m³/h]	Przepływ min [m³/h]	Przepływ max [m³/h]	P_{min} [MPa]	P_{max} [MPa]	L_{min} [mm]	L_{max} [mm]	Pusta rura
4	DN200	chodnik dojściowy do # I	238 509	240 790	2 281	95,0	33,3	149,5	1,508	1,68			
5	DN200	Przekop E-1 p.o. 600 m	154 018	155 506	1 488	62,0	31,7	130,5	1,449	1,67			
6	DN150	skrzyżowanie przekopów kołowych E-1/E2	122 085	123 132	1 047	43,6	10,9	67,7	1,02	1,572			
7	DN150	przekop E-3 p.o. 3650 m	75 873	76 290	417	17,4	0,0	105,1	0,287	1,502			
9	DN150	Przekop P-1 p.o. 200 m	10 495	10 885	391	16,3	-17,2	60,0	1,416	1,668			
12	DN150	#I strona wozów pustych	123 736	125 104	1 368	57,0	39,6	88,2	1,233	1,646			
13	DN150	#I strona wozów pełnych	3	3	0	0,0	0,0	0,0	1,224	1,637			
14	DN150	przekop taśmowy C-1	0	0	0	0,0			0,002	0,002			X
15	DN150	przekop taśmowy C-4	15 238	15 534	296	12,3	0,0	21,3	1,13	1,535			
16	DN150	przekop do szybu „Szewczyk"	35 638	36 392	755	31,4	13,0	53,2	1,201	1,622			

P_{min} – minimalne ciśnienie zarejestrowane w analizowanym okresie
P_{max} – maksymalne ciśnienie zarejestrowane w analizowanym okresie
L_{min} – minimalny poziom zarejestrowany w analizowanym okresie
L_{min} – maksymalny poziom zarejestrowany w analizowanym okresie

Fig. 8. Daily report for fire system pipelines

KWK PIAST-ZIEMOWIT RUCH ZIEMOWIT
System monitorowania sieci rurociągów w wyrobiskach dołowych w KWK Piast-Ziemowit Ruch Ziemowit
Raport za okres od 2023-05-12 00:00:00 do 2023-05-12 23:59:59
odwodnienie

Nazwa	DN	Opis	Przepływ początkowy [m³]	Przepływ końcowy [m³]	Przepływ za okres [m³]	Przepływ średni [m³/h]	Przepływ min [m³/h]	Przepływ max [m³/h]	P_{min} [MPa]	P_{max} [MPa]	L_{min} [mm]	L_{max} [mm]	Pusta rura
8	DN150	krzyżowanie przekopu P-1 z przekopem K-2	103 847	105 128	1 281	53,4	52,9	53,8	0,544	0,546			
10	DN200	Przekop P-1 – rurociąg odwadniający	165 542	167 560	2 017	84,1	58,5	224,1	0	0			
11	DN200	spływ wody z pokładu 215	104 840	106 162	1 321	55,1	27,1	201,8	0,003	0,041			
17	DN300	rurociąg odwadniający w przekopie taśmowym C-4	9 144	9 144	0	0,0	0,0	0,0	0,059	0,074			
18	DN200	przekop kołowy C-2 p.o. 300	256 654	259 983	3 329	138,7	0,0	271,4	0	0,917			
19	DN200	rurociąg odwadniający w pochylni 950					-2,3	68,4	0,07	0,085			
20	DN250	Przekop kołowy C-4 przed chodnikiem 1203											
21		Poziom I - poziom wody									647	1 103	
22		poziom wody przy #I									456	1 963	

P_{min} – minimalne ciśnienie zarejestrowane w analizowanym okresie
P_{max} – maksymalne ciśnienie zarejestrowane w analizowanym okresie
L_{min} – minimalny poziom zarejestrowany w analizowanym okresie
L_{min} – maksymalny poziom zarejestrowany w analizowanym okresie

Fig. 9. Daily report for dewatering system pipelines

KWK PIAST-ZIEMOWIT RUCH ZIEMOWIT
System monitorowania sieci rurociągów w wyrobiskach dołowych w KWK Piast-Ziemowit Ruch Ziemowit
Raport za okres od 2023-05-12 00:00:00 do 2023-05-12 23:59:59
woda pitna

Nazwa	DN	Opis	Przepływ początkowy [m³]	Przepływ końcowy [m³]	Przepływ za okres [m³]	Przepływ średni [m³/h]	Przepływ min [m³/h]	Przepływ max [m³/h]	P_{min} [MPa]	P_{max} [MPa]	L_{min} [mm]	L_{max} [mm]	Pusta rura
1	DN200	Poziom -147 - woda pitna szyb Piast II	161 792	163 733	1 941	80,9	74,1	88,5	0,001	0,001			
2	DN150	Poziom -147 - woda pitna szyb Hołdunów	107 671	108 951	1 280	53,3	52,6	54,0	0,001	0,002			
3	DN200	Poziom -147 - woda przemysłowa szyb Piast II	281 711	284 086	2 375	99,0	85,5	104,5	0,004	0,004			

P_{min} – minimalne ciśnienie zarejestrowane w analizowanym okresie
P_{max} – maksymalne ciśnienie zarejestrowane w analizowanym okresie
L_{min} – minimalny poziom zarejestrowany w analizowanym okresie
L_{min} – maksymalny poziom zarejestrowany w analizowanym okresie

Fig. 10. Daily report for drinking water system pipelines

Access to the system and its advanced features is only available through defined user accounts. Authorized users are allowed to change, among other things, the location of measurement points, replace maps of sections, define alarm thresholds, etc. Users with higher authorization levels have the right to manage other users and their authorizations.

5. SUMMARY

As part of the upgrade of the flowmeters installed on the pipelines of the dewatering system, both water flow and pressure sensors were included. Having information on the flow and pressure, the mine can conduct diagnostics of the state of pumps and pipelines of the dewatering system; e.g. a sudden increase in flow and a decrease in pressure on the pipelines of the dewatering system indicates a leak; indication of an empty pipeline – may mean the dewatering pump is air-locked or there is a leak between the measurement point and the pump (or in the pump itself), and the backflow of water may signal a power outage of the pump or its failure.

Measuring the volume flow (flow rate) and pressure of fresh water through built-in sensors allows the rapid identification of water shortages in operating areas. In order to locate failures in the fire protection system as quickly as possible, sensors have not only been installed on the supply pipelines to installations located in the vicinity of the shafts, but also in the cross-cuts.

The failure detection in fire pipelines in cross-cuts and their branches, whose length is more than 60 kilometres, is time-consuming, and has been greatly accelerated with the use of real-time information from the SYSMON system as well as the data logged from sensors at strategic locations, which significantly minimizes longwall downtime.

An additional benefit of the system is generating alerts based on predefined warning and alarm thresholds, which allows immediate response to incidents. Users can set signalling thresholds for both falling and rising water pressure and flow.

As a whole, when talking about real water management, it is important to know the present condition, that is, to know what is being managed. On this basis, further stages of digitalization including automation can be introduced.

The Ziemowit Operation is self-sufficient in terms of water consumption both for technological and domestic purposes. Precise monitoring of pipelines allows the maintenance of installation parameters at a level sufficient for technological and mine fire safety purposes. The system also provides for the detection of emergency conditions, leaks and monitoring of water levels in storage reservoirs, while in terms of hydrogeology it is used for water balancing. Flowmeters installed at the pumps allow the actual measurement of pump performance, determine their efficiency, and thus allow diagnostics to anticipate future failures and take preventive measures. Through the use of the system, quick diagnostics of the failure site and its immediate repair, the safety of the crew working in the underground workings has increased significantly.

Monitoring of the fire, process, and drinking water pipelines can make it possible to abandon other, less accurate methods of estimating the amount of water, including the method of measuring water based on the operating time of mine dewatering pumps and their rated capacity [3]. At the same time, a foundation is being established for more effective use by Ziemowit Operation of the hydrotechnical method of reducing the discharge of saline mine water [4].

The monitoring system enables the deployment of remote control of gate valves intended to control the flow of water in drinking and process water pipelines. Flow control will be carried out from the surface and will enable the mine services to instantaneously redirect the required amount of water to supply the fire system. By monitoring and controlling the amount of water, the system of drinking and process water management will change; the mine will reduce the amount of drinking water that is currently used to supply the fire system, and increase the use of process water for that purpose. The surplus of treated water obtained may allow, through pipe relining, to balance the amount of water purchased at the Piast Mine in the future. Such measures will bring savings due to the discontinuation of the purchase of water by the Piast Mine, while the sales of water to outside entities should bring profits.

The underground water monitoring and visualisation system employed at the Piast-Ziemowit Hard Coal Mine, Ziemowit Operation has become very useful to the staff from the very beginning of its operation, and allowed them to pinpoint the causes and remove inaccuracies in data readings already at the initial stage.

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GRZEGORZ WĄS, M.Sc. Eng.
ADAM KLUSKA, M.Sc. Eng.
MAREK SOBOLOWSKI, M.Sc. Eng.
MARCIN GARBACZ, M.Sc. Eng.
MARCIN PAŁKA, M.Sc. Eng.
Polska Grupa Górnicza S.A.
Oddział KWK Piast-Ziemowit Ruch Ziemowit
ul. Granitowa 16 , 43-155 Bieruń, Poland
{g.was@pgg.pl, a.kluska}@pgg.pl

MAREK WOJTAS, M.Sc. Eng.
Elsta Elektronika Sp. z o.o.
32 Janińska street, 32-020 Wieliczka, Poland
marek.wojtas@elsta.tech