

ANTONI WOJACZEK

Telematics in underground mining

Telematics denotes new telecommunication functions connected with the informatics domain. In this paper, these issues have been referred to selected telecommunication and informatics systems applied in Polish mining plants. Using a DGT IPnova telecommunication server as an example, a teleinformatic network was presented in an all-plant communication network. In this aspect, selected dispatcher monitoring systems of the basic engineering processes in underground mines were discussed, paying attention to the fact that a fiber-optic network shall contribute to telematic system development.

Key words: *mining telematics, mining telecommunication systems, monitoring of machines and devices*

1. INTRODUCTION

The word “telecommunication” (in French: *télécommunication*) was used for the first time in the book of French engineer Édouarda Estaunié entitled “*Traité pratique de télécommunication électrique*”, published more than 110 years ago [1]. Since that time, several dozen expressions have appeared in which this Greek prefix *tele* (“distant,” “far away”) occurs. Today, we frequently use such concepts as telephone, teletransmission, telemetry, telecontrol, television, and teletechnique. Some of them drop from common use (for instance: telegram (cablegram)

or, due to the huge development of contemporary telecommunication, are substituted with several new expressions (for instance, teleelectric).

The contemporary definition of telecommunication included in the Polish Telecommunication law [2] denotes broadcast, reception, or transmission of information (whatever it is) using cables, radio, or optic waves or other means by applying electromagnetic energy. Thus, telecommunication is a domain of science and technique as well as human activities related to the distant transmission of messages by means of electrical signals through telecommunication channels (Fig. 1).

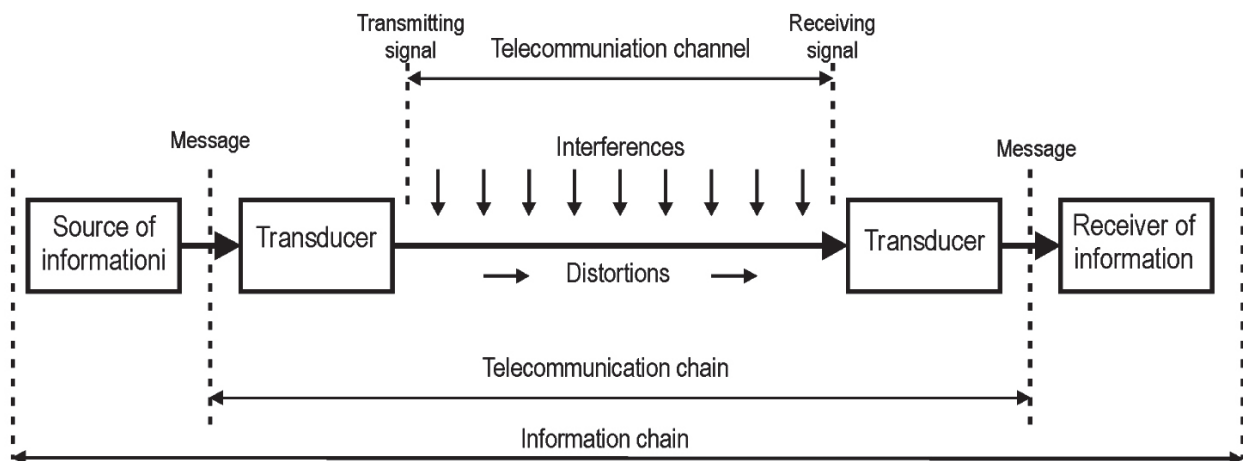


Fig. 1. Telecommunication and information chain

The development of computer engineering and necessity to transmit related information between computers led to the creation of the concept of teleinformatics [3]. At the turn of the 20th century, the abbreviated expression spread (i.e., telematics). Making an analysis of the various cases of the usage of the concept “telematics,” we may find that it is used as follows [4]:

- in relation to the structural solutions in which electronic acquisition and processing information make the integral elements of a telecommunication system,
- in relation to the technical solutions that integrate telecommunication and informatics systems.

Thus, telematics is the determination of new telecommunication functions connected with the informatics domain. Due to the various applications of informatics in the technique, this expression appears together with an adjective that determines the application domain; for instance, telematics of transport and medical or industrial telematics. Mining telematics are informatics systems that are applied in solutions for mining, integrating telecommunication with the informatics applied to these systems.

2. MINING TELECOMMUNICATION SYSTEM

In order to connect an information source with an information receiver, we create an information chain (and inside it, a telecommunication chain) (Fig. 1) in which a mining telecommunication server plays an important role. Information sources are most-frequently physical magnitudes that, in a processing apparatus, are changed into signals entered to a transmission channel utilizing an appropriate medium.

In underground mining works, a transmission channel may use the transmission media as follows:

- symmetric copper cables and leakage feeders [5],
- fiber-optic cables [6],
- electromagnetic waves (in mining radiocommunication) [5],
- signaling cores in cutter-loaders cables (for instance, the SMOk¹ system) [7].

A transmission channel may contain several sections utilizing various media and transmission devices.

A signal from the output of the transmission channel is converted in the processing apparatus to a message useful for the receiving person.

Telecommunication systems in mines most-frequently execute services of cable communication (telephone, alarm, loudspeakers) [1] or radio communication. Besides voice communication services within the recent years in underground mining works, one can observe a large development of other services (mostly teleinformatic services), which are listed in Table 1 [6].

In all services accomplished by telecommunication systems operating in mines, solutions are applied that are used appropriately for informatic systems. Figure 2 presents a simplified block diagram of a telecommunication system of an underground mine [8]. Making an analysis of this drawing, we may notice that information about most underground telecommunication systems is collected, processed, and then visualized in the servers of plant dispatcher rooms. In general, we may state that a mining telecommunication system accomplishes its services connected with voice communication (left side of Fig. 2) as well as being appropriate for teleinformatic systems supervised by servers that visualize the engineering processes on monitors (M) in plant dispatcher rooms and other decision spots of a mine. The arrows in this drawing present the basic direction of information flow.

The separate symbols in systems connected with mining communication denote the following:

- telephones (T) and telephone-signaling devices (TS),
- radio-telephones (RT),
- loudspeaker devices (UG),
- panels of dispatcher and alarm communication (PD, PA),

whereas information sources appropriate for teleinformatic systems are as follows:

- gasometry meters (MG), methane detectors (CH₄), and mine station (SD) of these systems together with execution elements whose basic task is to switch off the electric power supply of hazardous areas (Wz),
- geophones (G) and seismometers (S) of mining geophysics systems,
- cameras (K) of vision monitoring systems,
- channel transmitter (NK) of transmission systems (mainly bi-stable signals),
- controllers (PLC) in basic mining machines,
- digital protection in underground medium voltage switch bays (SN).

¹ Abbreviated name: system monitorowania kombajnów [loader and cutter monitoring system] of SOMAR company.

Table 1
Teleinformatic services executed by telecommunication system in mines

Executed service	Characteristics
Telemetry (gasometry)	These are mostly telemetric systems that monitor mining atmosphere condition and automatically switch off electrical devices in case of danger. As subscriber devices in these systems, methane detectors are applied as well as meters of carbon monoxide, air velocity, temperature, pressure difference, etc.
Bi-stable signal transmission	In these systems (for instance, FOD) transmission (with one subscriber pair), it is possible to 30 bi-stable informations from signal sources (sensors, contacts) dissipated in various headings. These systems monitor operation conditions even several hundred mining devices.
Monitoring (television)	Monitoring (preview) of important mining devices as well as headings (shaft bottom, stations, transfer points). These systems use cameras and optical fiber networks.
Monitoring (of parameters of machines and devices)	In mines, basic machines and mining devices are monitored. Data from these devices could be transmitted to the surface while using: – modem transmission in copper cables (for instance, SMOk system), – optical fiber networks, – leaky feeders, radio communication systems. Data from the servers of these systems are backed-up and then visualized in dispatcher rooms and other decisive spots of a mine.
Monitoring (localization, identification)	Systems that execute these services make possible zone localization as well as identification of persons equipped with personal identifiers or machines (among others). Localization together with identification is accomplished by identifier readers arranged in specified spots of the headings.
Visualization (of engineering processes)	Visualization analysis (i.e., graphic methods of creation) and transferring information about selected engineering processes are accomplished by the use of the following: – mosaic synoptic tables in plant dispatcher rooms; light elements of these tables are controlled from a bi-stable signal transmission system, – computer monitoring and visualization systems of engineering processes; data is made available by visualization systems dedicated for mines (for instance, ZEFIR, SAURON, THOR, etc.) using SCADA ² software.

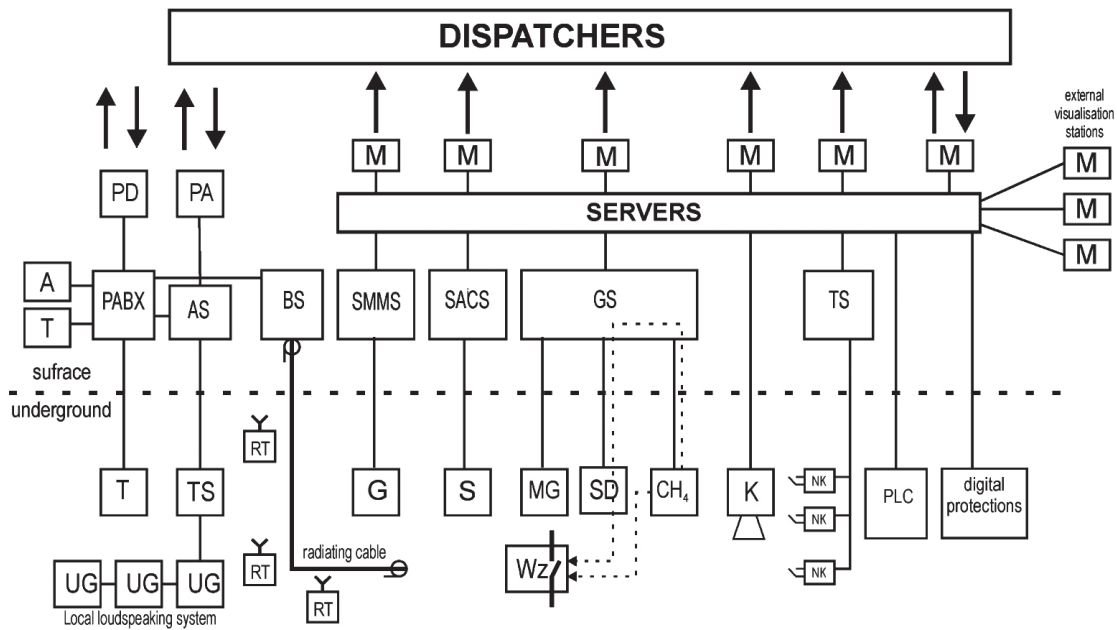


Fig. 2. Simplified diagram of standard telecommunication system of underground mines. PABX – private automatic branch exchange, AS – dispatch alarm station, BS – base station for radiocommunication system with radiating cable, SMMS – seismometric station, SACS – seismoacoustic station, GS – gasometric station, TS – transmission station

² SCADA – supervisory control and data acquisition.

Attention should be paid to the technical environment of mine undergrounds putting atypical requirements (restrictions) to telecommunication systems that, in fact, are represented in the design and structure of telematic systems in mines. Basic environment restrictions within the scope of the wider application of many new solutions applied in telematic systems are presented in Table 2 [9].

3. TELEMATICS IN MINING TELEPHONE COMMUNICATION

The basic function of every mining telephone exchange is to create an opportunity to switch the subscribers' terminals connected to it. An increase in digital telephone exchange functionality as well as the alteration of regulations within this scope [10–12]

caused a large expansion of their control part that led to the creation separated computer network that contained a series of computers, including the appropriate software executing such functions as recording conversations, voice mail, telephone book, automatic measurement of transmission lines, message dissipation, subscriber identification, registering and scaling of charges of telephone talks, database edition, etc. As a result of such an expansion, a telephone exchange became a telecommunication server because, despite the communication functions appropriate for telephone exchanges, they also accomplish many functions proper for informatic systems [13].

Telecommunication servers play a significant role in the integration processes of a communication system with alarm systems, gasometry, and connection of telecommunication servers of linked and multi-shift mines [6].

Table 2
Basic restrictions in using telematic systems in mines

Restriction	Characteristics
Explosion-proofing (anti-explosiveness)	In mines with the increased threat of methane and/or coal dust explosions, the underground devices and underground interfaces of the telecommunication lines should be explosion-proof. Underground devices of telecommunication systems should have an intrinsically safe design or optical safe (feature "op is" according to PN-EN 60079-28) that make it possible to operate in any methane concentration.
Device housing protection degree	Due to humidity, salinity, and the presence of dust telecommunication devices as well as devices that cooperate with these systems, the workings should have a minimum IP54 (International Protection Rating.)
Structure of workings	Small lateral dimensions of dog headings (several meters) in relation to their longitudinal dimensions (up to several kilometers); extensiveness of headings and necessity to use tree structure of telecommunication networks.
Eletromagnetic environmen	There is a large accumulation (in limited space) of network and electro-power devices of very large power in headings; difficulties exist with the effective separation of electro-power (including SUPO) and telecommunication earth electrodes; a telecommunication network with armored cables as well as electro-power ones along long sections of headings run in parallel within small distances should first of all be limited by the lateral dimensions of the headings.
Limited continuity of power supply of underground telecommunication devices of electro-power network	The power supply continuity of devices is limited by: <ul style="list-style-type: none"> – switching off in electro-power network according to plan (for instance, accomplishment of repairs) as well as periodic testing the switching off systems of electro-power devices that are performed by gasometric systems, – unplanned shutdowns induced by the actuation of electro-power and methano-metric protections. Exceeding the methane detector alarm threshold in a heading causes the automatic switching-off of the power supply in a given area. An increase in carbon monoxide concentration or lack of minimum air flow could also be reasons for alarms or shutdowns of electric power.

Figure 3 presents a simplified block diagram of a single-section DGT IPnova telecommunication server, most frequently applied in Polish underground mining plants in which the simplest self-contained

teletinformatik network LAN is marked. To the switch of this network, besides the control units (JS), the below-mentioned servers are connected to conversation recording system (NetCRR), additional services (SUD),

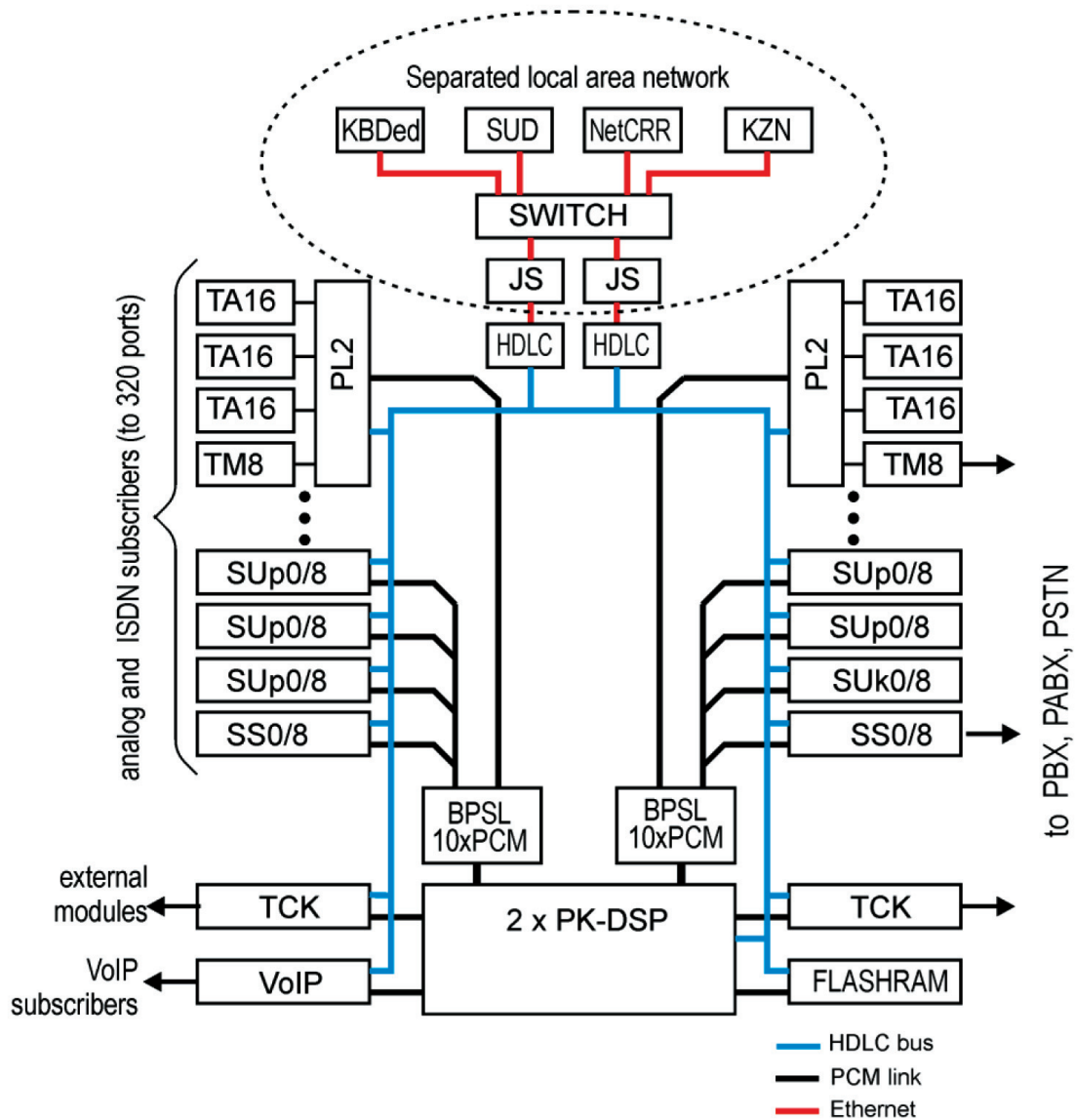


Fig. 3. General architecture of single-section DGT IPnova telecommunication server; PL2 line processors, PK-DSP – switching network FLASHRAM processors of tone signals and verbal messages, BPSL line buffer

database edition (KBDed), remote supervision (KZN), etc. This server may handle not only subscribers equipped with analogue telephones (TA16) or digital ones of various standards (SUp0, SS0, SUk0) but also VoIP subscribers. The server in a LAN network may fulfill one of two basic informatic functions:

- within the scope of the hardware – these are industrial computers that render specified services, usually making available their resources for other computers or that intermediate in transferring data among computers,
- within the scope of the software – this specific software installed (program, database) that render services on behalf of other devices or systems (for instance, gasometric, visualization) connected to the same LAN network in a mine.

Usage of computer networks (abbreviated term – VoIP³) is a relatively new method of executing telephone communication in mines. In this type of network, the transmission of packets exists that contain voice in a digital form. Contemporary telecommunication servers in mines make it possible to connect to an all-mine communication system; the VoIP telephony subscribers by means of a VoIP card furnished with an Ethernet interface. To the self-contained LAN network (or the digital ports of the DGT IPnova telecommunication server), teletransmission devices could be connected to other telecommunication systems (gasometry, data transmission, visualization, alarms).

³ VoIP = Voice over Internet Protocol

4. TELEMATICS IN MONITORING SYSTEMS

The first monitoring systems in underground mines have been executed for 40 years in methanometric dispatcher rooms (CTT63/40U exchanges). At the same time, the bi-stable monitoring of machines and mining devices became current (CTT-32 system). It had feature of observation of the so-called “extreme conditions”: (for instance, operation/standstill, open/closed, full/not full, etc.) [7, 14]. For over twenty years, the combined cutter loader has been equipped with a computer control system together with event recording and a backup system. The remote monitoring of machines (from the surface) and mining devices commenced at the turn of the 20th century by implementing the SMOk system at the Bogdanka Mine, which uses modem system of information transmission to the dispatcher room of the plant. Thus, in dispatcher rooms of mines, there are two types of information on machine conditions or devices available:

- basic information – bi-stable monitoring gained most-frequently from systems of multiple signal transmission (for instance, FOD, UTS, CTT-32),
- advanced information (analog systems) – obtained from the controllers of mining machines and devices and also from digital protections in switch bays or from gasometric systems.

In ninetieth, the ZEFIR system became current, which was the first dispatcher room system of visualization using IBM PC personal computers operating under the control of a DOS system. At the beginning, this system collected data from a bi-stable transmission system and performed its visualization. ZEFIR (after many technical and program modifications) is in operation up to the present day, providing a lot of informal standards within the scope of the operation of computer monitoring systems and visualizations in mines [7].

At present, for the current supervision of machines and mining devices as well as electro-power networks, the monitoring systems are applied that most-frequently use SCADA-type software. The basic tasks of such monitoring systems are as follows [6, 7, 14]:

- acquisition and backup of signals from devices being monitored (for instance, measurement results),
- visualization of condition of devices being monitored in supervision spots,
- remote control of machines and also control of switches in switch bays,
- alarming about the incorrectness of their condition,
- development of reports (for instance, for needs of manufacture supervision).

At present, copper symmetric cables are the basic transmission medium in underground mines. On average in a typical mine, over 1000 pairs are operated [7, 9]. This results from the fact that many terminal devices (methane detectors, telephones, and alarm-signaling devices) require a central power supply from the surface of the mine. In telematic systems, the acoustic frequency band is used for the transmission of bi-stable signal transmission (FOD-900, UTS), with access, by the way, in gasometry, where telephone modems are mainly utilized for leased lines, and in some systems frequency transmission (up to 12 kHz), in seisometry and seisomacoustics as well as for monitoring machines and mining devices with the utilization of narrowband telephone modems for leased lines. Telephone modems in mines can operate with a flowability of up to 33,600 kb/s in symmetric lines with a core diameter of 0.8 mm.

Bands of higher frequency in underground mining plants could be operated in data transmission systems (for instance, as an RS485 interface or using Lon Works protocol; unfortunately for relatively short distances only [transmission range up to 2 km], whereas in higher frequency bands, wideband modems are very rarely used (for instance, SHDSL modems made by the WESTERMO company) [15].

Restrictions connected with the widespread nature of workings necessary to provide intrinsic safety in underground teletransmission networks and maximum transmission velocities possible to obtain in copper cables caused that, in parallel to copper networks, the fiber-optic networks are constructed in mines are used first of all for monitoring systems of machines and mining devices.

The properties of the separate transmission media are specified in Table 3 [15].

Attention should be paid to the fact that contemporary telematics (i.e., IED) installed to it decides mostly of possible scope of machines and mining device monitoring. The presence of IED devices makes it possible, by measurement, to obtain much precise information about the values of measured electric magnitudes (current, voltage, power, electric energy) as well as allows for their remote control. Analysis of the present condition of the IED⁴ devices installed in underground mines indicated that several various visualization systems are applied in parallel in mines. Some of them are used by the main dispatcher, others by the methanometry dispatcher, and still others are applied in energeo-mechanic dispatcher rooms or used to control transportation.

Table 4 (in alphabetic order) presents the examples of dispatcher visualization systems used in Polish mines [8, 14].

⁴ IED – intelligent electronic devices.

Table 3
Comparison of transmission media properties for underground mines

	Symmetric copper cables	Symmetric copper leaky feeders	Optical waveguide cables	Radio connections
Range	from 100 m for 1 GB/s, up to over 10 km for telephone band	up to 500 m, necessity to construct infrastructure with repeaters	up to several dozen of km <1Gb/s	several hundred m, access infrastructure is necessary
Remote power supply	yes	yes	no; yes (hybrid cables)	no
Effect of connections	negligible	small	significant	n.a.
Flowability	up to 1Gb/s, the higher frequency the shorter range	up to several hundred MHz (modems, wideband)	up to 1 Gb/s	up to several dozen MB/s
Connection engineering	easy	easy – requires interfaces	difficult – requires advanced tools (fiber bonding)	n.a.

Table 4
Examples of systems for supervision, control and visualization applied in mines

System name	Manufacturer	Notes
DEMKop	SOMAR	Mining visualization system dedicated especially for energomechanic dispatcher rooms of mining plants as tool software; hardware solution is SMoK system
e-kopalnia (e-mine)	FAMUR	Remote supervision system of mining machines (set of teleinformatic, hardware solutions, and measurement tools). Elements of these system are: control devices (for instance, FAMAC: MRS, OPTI, DMP), explosion-proof informatics hardware (for instance, server, LS local station, MPC I computer), as well as diagnostic hardware and software systems.
EMAC	ENERGO TEST	System dedicated for electro-power networks; it cooperates with PLC controllers of electro-power devices of various companies and with other protections provided with explicit communication protocol.
EP7-SMP	ELPRO7	Monitoring system for ELPRO underground pump station.
eSPiM CSBiRE	WINUEL	Electronic measurement and settlement system of energy; visualization reporting system, simulation, and planning analysis as well as management of electric power consumption; applied in KGHM.
MonSteer-D	Tranz-Tel	Dispatcher supervision system; tool software; hardware solution is, for instance, FOD system.
SAURON	RNT	SAURON visualization system has interfaces for communication with IED of mining devices as well as dedicated software applications such as: Pumping station, 6 kV grid, Haulage, Longwalls, Mine faces, Skip hoists, Air conditioning.
SD-2000	EMAG	Dispatcher visualization system; tool software
Smart Wall	Elgór+ Hansen	Control, monitoring system of machines and mining devices. System is provided with hardware elements (for instance, flame-proof EH-O/06 computer, EH-O/01 control panel, EH-O/03 separator) as well as software (for instance, KESSA-ATON, EH-WallView, EH-MineView).
SP3	HASO	Industrial processes presentation system (SP3); tool software.
SW μ P	HASO	Computer-aided system for dispatcher of methanometry; tool software.
SYNDIS (RV)	MIKRO NIKA	Supervision, consulting and control system for industrial installations; dispatcher monitoring and control system of electro-power system operation of a mine is applied in KGHM.
THOR	SEVITEL	Dispatcher system: visualization, monitoring, backup, reporting, and control; tool software.
WIZAS	Becker Warkop	Visualization system of longwall machines with dedicated controllers of BECKER company.
WIZCON Superwizor	Wizcon@ Systems SABUR	Dispatcher system for inspection of manufacture and safety parameters with WIZCON visualization module; industrial software that allows management, monitoring, and control of engineering processes using Internet browser.
ZEFIR	PRUNELLA	Most-frequently applied in mines, the dispatcher visualization system dedicated for plant dispatcher room, dynamic synoptic table; tool software.

5. SUMMARY

At present, telematics in monitoring systems are developing the fastest among all other telecommunication services in mines. The monitoring of machines, devices, and the environment is always connected with the necessity to install new controllers as well as to modify the outfit and software of already-existing controllers, and also with construction of fiber-optic telecommunication lines in the cable network bus [15].

The implementation of monitoring to new engineering areas in mines should be, however, preceded with an analysis that would take into consideration both the telematics costs and its significance for the entire supervision of the engineering process in the mine or diagnostics of separate important devices.

Monitoring in a mine should be started from providing machines and mining devices with intelligent electronic devices (IED) and such automatic systems that make their remote control possible.

An increase of efficiency in a mine could be achieved with several methods. One of the most-advantageous methods to achieve this goal is:

- increase of effective operation time of machines and electrical devices operated in mining plant,
- minimization of standstills; i.e., time lost for uncontrolled failures of machines and devices as well as cutting down the time of interoperation duties (for instance, machine transfer).

These goals may be achieved by the implementation of modern telematic systems in mines. Unexpected failures should not occur in mines; thus, a special emphasis should be placed on monitoring the electrical devices mainly from the point of view of the earlier detection of incorrectness of their work as well as the proper preparation of any planned repairs.

One should realize that, due to the necessity to install telephone communication devices in headings, alarm system signaling devices and gasometric system sensors are copper cable and still shall be installed in all passages of underground headings. However, they cannot constitute the basic element of a teletransmission system in telematic systems. In order to monitor important energomechanic objects, the fiber-optic networks are to be utilized in mines.

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ANTONI WOJACZEK, prof.
 Department of Electrical Engineering
 and Automation in Industry
 Faculty of Mining and Geology
 Silesian University of Technology
 ul. Akademicka 2, 44-100 Gliwice, Poland
 awojaczek@polsl.pl