Devices and means of control of underground facilities based on PLC technology

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Abstract. The article presents a solution for data transmission via electrotechnical communication lines, based on the testing of capacitive and inductive connection devices. The article contains information about modern systems for monitoring and control of technological equipment in the mine, for communication, alarm, monitoring and alerts. The principles and features of the Power Line Communications system are described. The relevance of the introduction of PLC technology in the control system of hard structures is described.

1. Introduction
Nowadays more and more mining enterprises use new technologies for automating and monitoring mining processes, gradually replacing the “past generation” equipment. Due to this fact, the work efficiency grows significantly, the ore mining volume increases, all regulatory requirements are fulfilled and the safety and harmlessness of the working environment are ensured. However, all new developments in this area are implemented at the expense of additional communication lines to transfer a large amount of information in the mining automation system [1].

2. Modern monitoring systems.
As for different systems of technological equipment control and automation in underground structures, it is more expedient to consider systems that collectively have the ability to cover all production areas in one information network, with output to a single dispatch console. The so-called “Smart Mine” is a single information and control complex designed to monitor and control technological equipment in the mine, provide communications and alarms, monitor, alert and search for people caught in an accident. This complex includes:

1. "Granch MMS” system is a multifunctional measuring system of aerogas control, communication, information transfer and equipment control, designed to solve automation problems of technological processes in the mine. Due to the technical devices that make up the Granch MMS, such automated systems as aerogas control, management of conveyor transport, mine drainage management, power management and many others have been created and now they successfully function.

2. “SBGPS” system is designed to determine the location of personnel, transport and cargo, alert and provide operational mobile communication to personnel located in mines; search and detection of people caught in the accident. This ensures the transmission of video, audio and telemetry data from technical devices compatible with the system; determines the volume fractions of harmful and hazardous gases and / or oxygen in the air of the working area and
provides an alarm when they leave the set limits. It is a part of a multi-functional coal mine safety system [2].

The main disadvantage of the above-described automated control and monitoring systems is that it is necessary to create a new underground information infrastructure to read, collect and send data to the dispatcher’s control panel. Using fiber optic cables laid in underground workings, it is designed to transfer data from each section of the ore mining process to the dispatcher’s computer.

We propose to eliminate this disadvantage by introducing Power Line Communications technology (PLC) into all of the above automated control and monitoring systems. PLC systems use existing electrical power lines as a transmission medium to provide high-speed communication capabilities by combining radio frequencies on power lines. The most active in Russia is an enterprise “Hypercom”. Modern laboratories and the production of domestic electronic components make PLC technology affordable for Russian consumers.

3. PLC technology operation principle.

PLC includes two types of information transfer:

- 2.1 Broadband Information Transfer (BPL) up to several hundred Megabits and one Gbit per second. It is designed for use in such areas as building local networks, telephony, Internet access, video surveillance, integrated security systems, automated process control systems and automated information management systems with a large flow of processed information.

- 2.2 Narrowband information transfer (NPL) up to one megabit per second. It is designed for use in such areas as APCS (automated process control systems), AECAS (automated energy control and accounting systems), ACS (access control systems), FAS (fire alarm systems), smart home and various types dispatch [3].

The advantage of using electric power lines as a data transmission medium is that each mine and all enterprises are equipped with power lines that are connected to the electrical network. PLC carrier link communication systems use existing electrical wiring as network media to provide data transfer. Thus, it is possible to create a unified data network of the “Smart Mine” type from all mine sections to the dispatcher's control panel without the huge costs of laying expensive fiber-optic cables.

However, at the mining enterprises and other large enterprises, it is necessary to connect through special connection filters to realize this idea as the direct connection to powerful devices is impossible due to the presence of higher voltage (1100V constant voltage and 660V nominal). The connection devices can be both capacitive and inductive, which differ in the connection way [4].

4. Capacitive and inductive connection device.

The inductive connection method (Figure 1) implies the presence of an inductive component, with which a high-frequency signal is taken and transmitted to the modem. The advantage of the inductive connection method is increased security, if there is an increase in voltage or breakdown of the device, the high voltage does not fall on the modem itself. The disadvantage of this method is that at high voltage in the conductor, the inductive coil of the device is saturated with current that results in a conductivity drop, decrease in speed, range and quality of the communication channel [4].
The capacitive method (Figure 2) implies the direct connection to the line, thus it is protected from high voltage high-voltage capacitance. The advantages of capacitive sensors are simplicity, high sensitivity and low inertia. There are some disadvantages such as the influence of external electric fields, the relative complexity of measuring devices, the probability of equipment (modem) burning in case of a device breakdown [4].

5. Testing
When building a communication line based on the PLC technology, an important step is to connect the PLC equipment to the power grid. In the general case, the PLC network is built by connecting the PLC modem to power lines using a connection filter via a coupling capacitor or a single connection device. The modem is powered by the same power supply. The modem is connected to filters or devices by connecting via coaxial cable with BNC (SMA) connectors, and to the power supply via a power cable [3]. To determine the most effective way to connect the PLC technology to electrical networks in underground conditions, we have tested two connection methods: inductive and capacitive, to the SM130K tunneling machine. (Figure 3). The testing was carried out in the mine “Belkaly” in Soligorsk.

The graphs (Figures 5 and 6) show the spectra of the PLC signal obtained at the receiving side with different ways of connecting to the line. Comparing the spectrum levels, it can be seen that the capacitive method loses 15 ... 20 dB to the inductive one.
6. Conclusion
Summarizing the test results, we single out that the technologically inductive method is safer and, in contrast to the capacitive one, involves plugging in the cable without opening the cable armor, (Figure 4). In addition, the inductive method shows the best signal level when testing. Due to the obtained test results, we have decided to apply the induction connection method for the tunneling machine equipment to the electrical network of the Belkaly mine. The machine control equipment includes vibroacoustic sensors.

The mining industry is a labor-intensive, expensive and threatening industry. As a general rule, the so-called islands of automation are observed. For example, there may be up to four production areas where operators use their own equipment, while they are not interconnected. Thus, optimization of the value chain in mining is not an easy task, the key to the solution of which is to have a complete understanding of all the stages of processing raw materials and transporting finished products. The integrated solution will eliminate the gaps in the value chain, and a reliable connection between the production points will help, for example, to coordinate mine blasting and crushing operation with the grinding process and the work of the processing plant as a whole [5].

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