ANALYSIS OF POWERED ROOF SUPPORT OPERATION BASED ON A VIRTUAL DRIVER

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Abstract: The article presents the results of tests and analyses of control functions performed by a powered roof support which is the basic part of a powered longwall system. The research was based on an innovative registration and measurement system dedicated to this specific range of tests. The basic element of this system is a virtual driver. It is equipped with input and output systems to connect standard physical voltage signals. The tests were carried out on a prototype powered roof support type ZPR-15/35-POz. The presented research methodology and obtained results are an element of new research methods developed for powered support based on virtual controllers. The applied solution generates less costs than the devices currently used, while its functionality is significantly greater. The system developed by the Authors supports innovative and, to a certain extent, intelligent IT solutions for testing control elements. This developed system is suitable to be applied in a wide range of research such as diagnosis of mining machinery control elements and other industries in the near future.

Keywords: virtual controller, underground operation, powered support, mining.

1. INTRODUCTION

The global mining machinery market places very high demands on the manufacturers of longwall systems. All producers must, in addition to low product costs, also ensure their high quality due to the large competition. This, in turn, forces manufacturers to use reliable and effective methods and research tools. In particular, this applies to mining supports. Their primary task is to secure the working space in underground excavations during mining exploitation. The operation of the roof support also has a major impact on the formation of various types of threats, such as concerning ventilation (Brodny and Tutak, 2016a; Brodny and Tutak 2016b; Tutak, 2017) and fire (Tutak and Brodny, 2017; Tutak, 2017b). A powered roof support is a basic element of the underground safety system. Its task is to effectively protect the longwall working and support the work of the entire longwall system. The support constitutes individual sections, which in series form one technical system. One of the basic systems enabling proper work of the entire support is the control system. The efficiency of the entire operation process depends on its reliability and effectiveness. This system allows the implementation of individual functions, and thus its effective operation.

The powered roof support performs individual control functions which form a certain cycle that is repeated in the operation of the longwall system. The main functions carried out by the longwall support during the operation process include roof management, securing the excavation against falling rocks, protecting the excavation against rubble penetrating the working space, and moving the scraper conveyor and combine. Generally, the powered support implements the phases of the work cycle, i.e. withdrawing the canopy, moving the sections, expanding the roof support and moving the conveyor (Atul et al., 2010; Bartelmus, 2006). The implementation of these functions is enabled by a control system that is related to a single section and to a group of sections. Therefore, it is crucial to use an effective and reliable control system. A series of test is required prior to introduction of the system in to practice. The tests of control systems are expensive and requires a suitable testing station. In order to reduce these costs, the Authors of the publication developed an innovative system for testing the control system of the section of the powered roof support based on a virtual controller. The article presents methodology designed for tests based on such a controller. The research was carried out on a prototype section, which is also an original solution that can be successfully used in an electro-control system. The main goal of the research is to develop a wireless system, and thus an unmanned control system for a powered roof support. The use of such a system will significantly reduce the presence of employees in the face zone, which is one of the most dangerous areas in the mining exploitation process. The practical application of the system will also enable full monitoring of support operation parameters and their use for diagnostics of the operation state of the entire longwall system (Brodny and Tutak, 2018; Stecuła et al., 2017; Arputharaj, 2015; Johansson, 2010). The methodology and results presented here are part of the broader activities undertaken to increase work safety in underground mines, while improving work efficiency. The process of introduction the solution into practice is complex and should include steps aimed at assuring proper knowledge of employees about the functions as well as advantages and effectiveness of the system (Palka et al., 2017; Palka, 2017).

2. CHARACTERISTICS OF THE SYSTEM

The tests included a prototype section of a powered roof support type ZRP-15/35-POz. The aim of the research was to determine the parameters of its work based on a virtual controller built into the software of an innovative research system. The system is designed to determine, among other things, static and dynamic characteristics of control hydraulics. The system also tests control elements and can conduct visualization of work parameters of the powered roof support. This innovative system (Fig. 1) comprises a control and intermediary module that allows testing of the operation of individual control elements of the support.

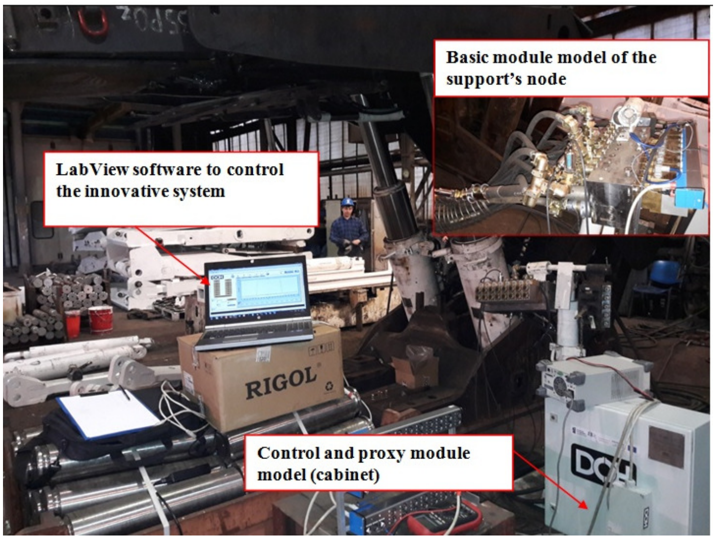

Fig. 1. An innovative research system for analysing the work of powered roof supports

This module was based on the National Instruments cRIO9030 card and is equipped with two different operator interface devices. The operator can communicate via Ethernet, using a PC. The control and intermediary module controls the basic node of the support (executive electrohydraulic block). A custom executive block for the implementation of the electrohydraulic functions of the control of the powered roof support was built for the basic module of the support's node. The window of the test stand application (Fig. 5) includes elements for selection of a method and control parameters of the valve installed in the roof support. The application enables determination of the PWM valve control signal curve. It is also possible to set the maximum signal fill, its time, descending time to the minimum value, its minimum value and the time of filling as well as the frequency of the PWM signal. The developed interface also allows the registration of selected characteristics for any registered signals (Szurgacz and Brodny, 2017; Atul et al., 2010).

3. RESULTS

The developed system was used to determine the work parameters of the prototype section of a powered roof support type ZRP-15/35-POz. The research consisted of recording the implementation times of the basic functions of the operation of the section. This concerned expanding and withdrawing sections (sliding out/down hydraulic legs, located between the floor bases and the canopies). The measurements included determining the time of switching the power supply on with the PWM signal and supplying the full signal to the basic functions performed by the longwall support.

Figure 2 shows the maximum (3.5 m) and minimum (1.5 m) operating range of the tested roof support.

Fig. 2. The maximum and minimum location of the section sectioning during work

Figures 3-7 present the operating characteristics of the control system for individual phases of the operation. Tables 1-5 present the results of the tests. The data considers the switching times of the power supply and time delays in its implementation for full and PWM signals. The presented results include various values of the controller's supply voltage.

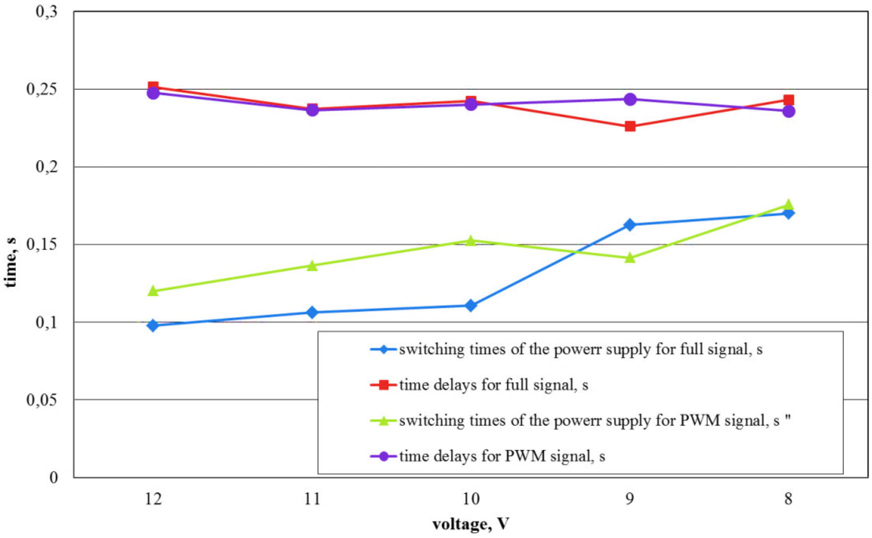

Fig. 3. Switching on and lag times with the PWM and full signal for sliding down mode

Table 1
The switch-on time and the time lag of the leg sliding down function

Voltage [V]	Switch on speed [sec]	Time lag [sec]
FULL POWER SUPPLY		
12	0.097579	0.251333
11	0.106191	0.237299
10	0.110516	0.242414
9	0.162631	0.226083
8	0.170024	0.243211
PMW POWER SUPPLY		
12	0.120126	0.247556
11	0.136259	0.236491
10	0.152467	0.240037
9	0.141379	0.243583
8	0.175569	0.235847

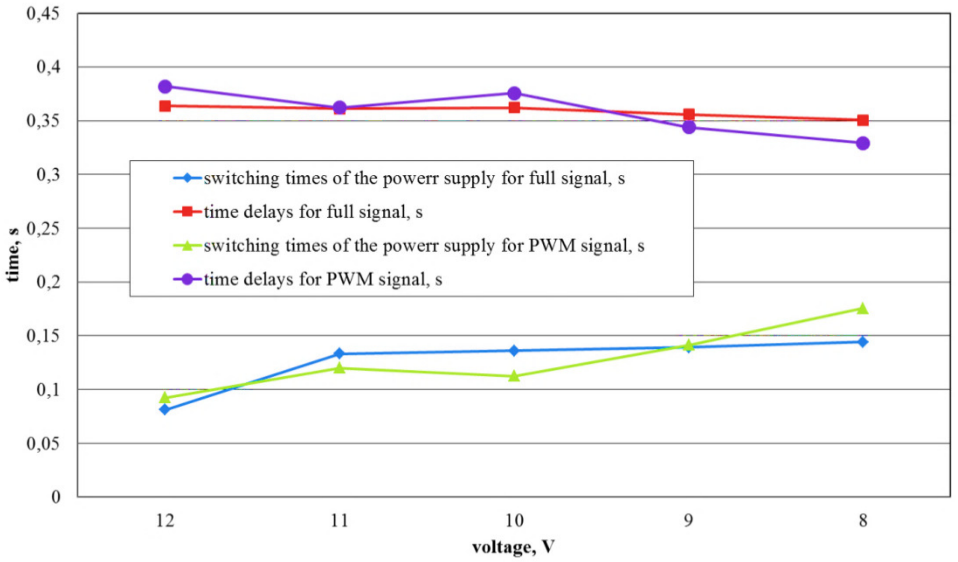

Fig. 4. Time of switching on and powering off the PWM signal and full for sliding out mode

Table 2
The switch-on time and the time lag of the leg sliding down function

Voltage [V]	Switch on speed [sec]	Time lag [sec]
FULL POWER SUPPLY		
12	0.081316	0.363696
11	0.133062	0.361127
10	0.136019	0.362157
9	0.139087	0.355846
8	0.144151	0.350437
PMW POWER SUPPLY		
12	0.092404	0.38193
11	0.120126	0.361991
10	0.112364	0.375576
9	0.141379	0.34393
8	0.175569	0.329356

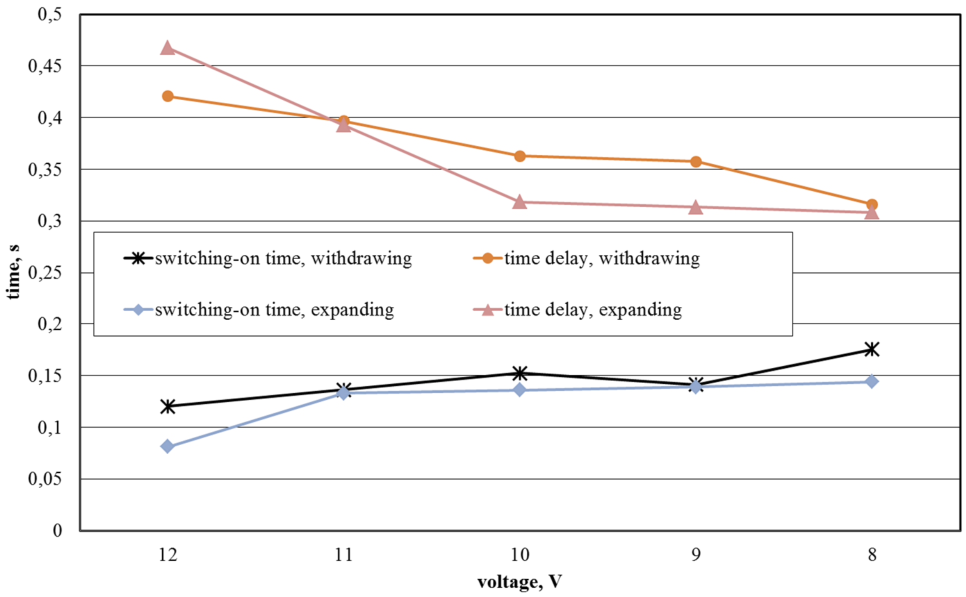

Fig. 5. Comparison of times for sliding out and down the legs, full power supply

Table 3

Results of time comparisons for sliding down and out the legs at full power

Voltage [V]	Switch on speed [sec]	Time lag [sec]
	SLIDING DOWN	
12	0.120126	0.420864
11	0.136259	0.396691
10	0.152467	0.363017
9	0.141379	0.357604
8	0.175569	0.316023
	SLIDING OUT	
12	0.081316	0.467566
11	0.133062	0.392534
10	0.136019	0.318426
9	0.139087	0.313361
8	0.144151	0.308427

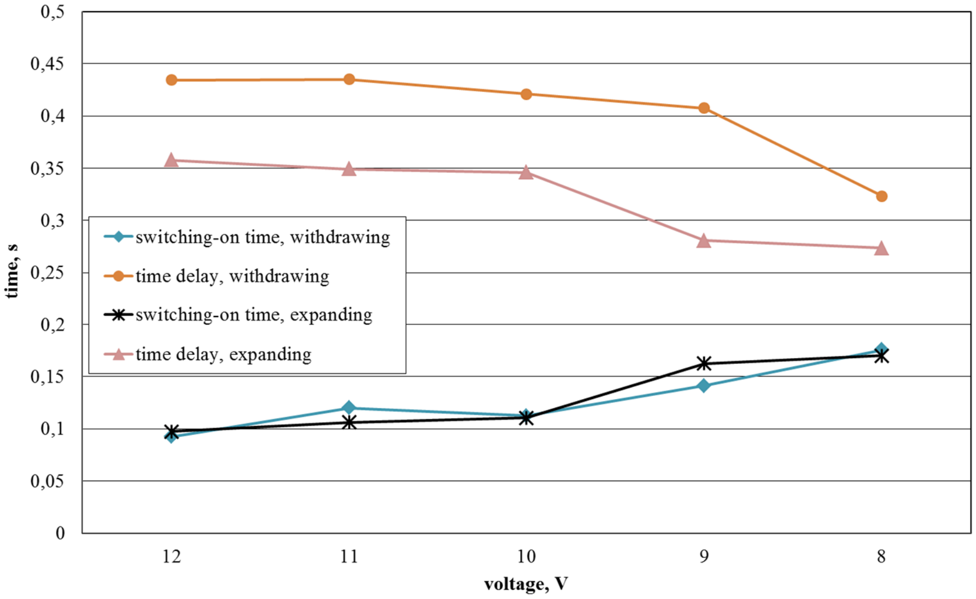

Fig. 6. Comparison of times for sliding out and down the legs, PWM power supply

Table 4
Results of time comparisons for sliding down and out the legs at full PWM

Voltage [V]	Switch on speed [sec]	Time lag [sec]
	SLIDING DOWN	
12	0.097579	0.35779
11	0.106191	0.349289
10	0.110516	0.345961
9	0.162631	0.280909
8	0.170024	0.273517
	SLIDING OUT	
12	0.092404	0.4343
11	0.120126	0.43515
10	0.112364	0.420883
9	0.141379	0.407503
8	0.175569	0.323416

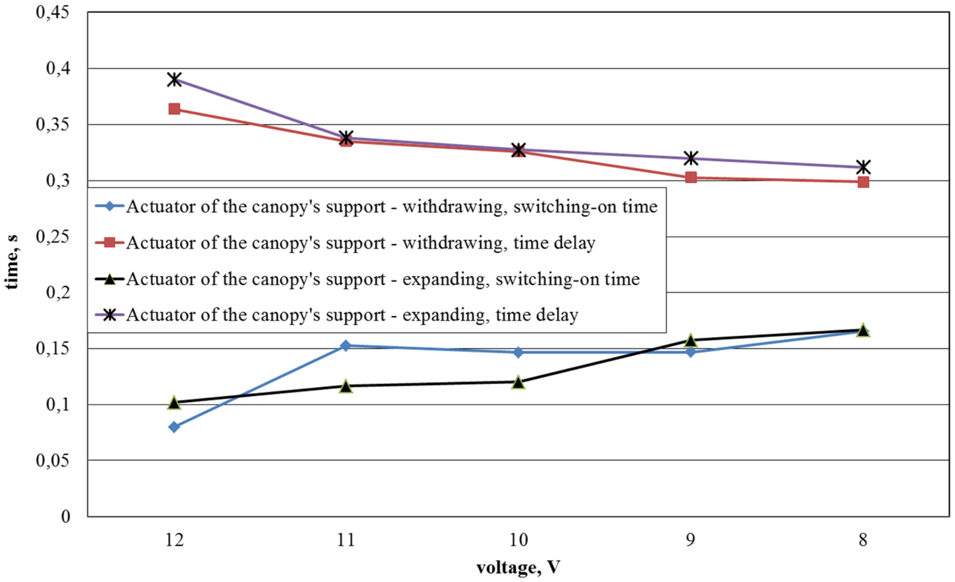

Fig. 7. Tests results for sliding down and up the canopy support's actuator

Table 5
Results of time comparisons for sliding down and out the legs at full PWM

Voltage [V]	Switch on speed [sec]	Time lag [sec]
	SLIDING DOWN	
12	0.079837	0.363703
11	0.152467	0.33515
10	0.146239	0.326003
9	0.146479	0.302624
8	0.16509	0.298607
	SLIDING OUT	
12	0.101645	0.390316
11	0.116429	0.3382
10	0.120126	0.32752
9	0.157087	0.319867
8	0.166327	0.311976

4. CONCLUSION

The study presents an example of the use of an innovative method of testing basic functions performed by a powered roof support. Its main element is a virtual driver which was developed and constructed for specific range of research. It is the basic part of the system designed to test innovative electro-hydraulic systems for controlling a powered roof support. The tests included measurement of system activation time for PWM signal and full signal for different values of voltage supplying the controller. On the basis of the conducted tests, it can be stated that the lower the valve supply voltage, the longer the switching on time, whereas the lower the valve supply voltage, the shorter the delay time. Delay times for PWM signal and full power supply are comparable. It can be assumed, therefore, that the use of virtual technology for testing prototypes of machines creates great opportunities for multivariate research. This saves time and allows a wide range of tests, which would generate substantial costs and be time-consuming when based on different methodology. Conducting research based on virtual modelling and simulation of the objective function is currently a very dynamically developing research area. The result are promising, therefore, the system should be applied to a greater extent in the mining industry.

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