Modeling of the complex “Technological equipment and Control system” for debugging and testing control algorithms of the walking support

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Abstract. The paper describes a method for verifying control algorithms of the APCS (automated process control system) applied software using a simulation complex that provides correctness control: execution of control commands, equipment state identification, control signals generation, etc.

1. Introduction
Modern development of technological equipment new samples is associated with the creation of appropriate automation tools that provide the required functionality of this equipment.

The control algorithms of automated process control systems (APCS) provide control and management functions for industrial equipment. The reliability of these algorithm’s functioning affects the safety of production processes. Errors made during the process control system development can lead to equipment failure, disruption of the process, and even to human losses. Control algorithm’s verification at the manufacturer’s factory allows the automated process control system algorithm’s functioning reliability control to be ensured.

In the work the model based design approach is used based on the designed system and the controlled process models use [1,2].

2. Technological equipment model (TEM)
The article [3] proposed the technological equipment model structure shown in figure 1. This model differs from the existing ones in that it allows the generation of sensor signals, control actions and control commands, and implements the application software functioning simulation.

As part of the research task, this approach was adapted to develop a walking support module [4] simulation model that provides simulation of technological equipment and application software functioning [5]. This model allows you to perform a consistent generation of signals and commands of the automated process control system, to render the three-dimensional model of the support module.
3. APCS applied software control algorithm model

The control program model is a control automaton that is convenient to develop using the automata programming approach proposed by A. Shalyto [6]. The model development involves the APCS signals and control commands specification preparation and the development of a finite state machine simulating the applied software functioning. The finite state machine can be formalized as a formula:

\[
FSM = \{S, S_0, A, Y, g, F\}, \tag{1}
\]

where \( FSM \) is a finite state machine describing applied software functioning, \( S \) – simulating model condition, \( S_0 \) – initial condition set at simulation start up, \( A \) – the input alphabet of the automaton (the state of the sensor signals and input control commands); \( Y \) – the output alphabet (control actions on the process equipment); \( g \) – transition function; \( F \) – finite states.

Piece of the control program state machine of the walking support module is displayed at the figure 2. This piece is control movements of the first section of the module. Each

![Figure 1. Technological equipment model structure.](image)

![Figure 2. Part of the walking support module control program model.](image)
condition (character S – state) defines output signals (character Y) to hydro drives walking support module. State transitions are performed by sensor signals changes (character X), time variables (character t) or control commands (character C).

Model of the walking support module may be controlled by these approaches:
1. Scenario (experiment program) – automatic control mode.
2. Automated by dispatcher control commands (agreements interaction between hydro drives of the walking support module by control program model with the automatically control mode).
3. Manual – dispatcher control by control commands execution for a separate hydro drive (dispatcher runs each step of the walking support module working cycles).

4. Simulation complex structure
The simulation complex proposed structure is depicted in Figure 3 (an optional link is outlined with a dashed line). It is implemented taking into account the use of MATLAB [7,8] as a modeling environment and its extension packages: Simulink in basic configuration, Simulink Stateflow, Simulink Animation 3D, and OPC Toolbox. OPC technology (abbr. From Open Platform Communications) [8] is used to interact with external software and hardware of the complex.

![](image)

Figure 3. Simulating complex structure.

The simulation complex is designed to simulate the coal mining process according to sublevel galleries mining technology and the technological equipment that provides it, such as “support-gallery”, moving as the sublevel strata are undercut along the seam sublevel gallery [10–12]. As one of the options for supporting the “support-gallery” type development to create an effective domestic extraction complex and to work out steep seams with sub-levels with the outlet is a walking support [13,14].

The functioning of the simulation complex is set by the models of the programs for controlling the technological process and equipment. The input of the structural scheme receives the control actions from the real or model application software and the sensor signals from the of the walking support module physical model. At the output of the block diagram, data is generated for the walking support module virtual analogue visual demonstration and data for controlling the walking support module model.

With the help of proposed imitation complex structure it is possible to perform:
- comparison of the generated control commands from the model and the real application software of the APCS, formed on the basis of the model sensor signals;
control of real and model sensor signals identity, with identical control commands. Additionally, it is possible to verify the correctness of the control algorithms when observing the three-dimensional visual animation of the model of the walking support module. The integrated model of the walking support module was created using the KOMPAS-3D computer-aided design system [15]. Three dimensions model visualization of the walking support module realized with the application Simulink Animation 3D of MATLAB.

TEM state control is performed by giving control commands manual or scenario modes. Additionally, to diagnose the complex operation, the control mode of the actuators in manual mode has been added.

5. Conclusion
The simulation complex developed structure, created using the approach of model-based design, will allow the development, debugging and testing of application software control algorithms of the walking support module advanced APCS.

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