ISSN 2223–5620 (Print), ISSN 2411–1554 (Online)
Електромагнітна сумісність та
безпека на залізничному транспорті, 2018, № 16

UDC 656.25

I. O. ROMANTSEV – Cand. Tech. Sc., associate prof., Dnipropetrovsk National University of Railway Transport named after akad. V. Lazaryan, rio_mail@i.ua

EMULATION OF THE WORK OF THE ABS POSITION OF THE PULSE-WIRED AUTOMATIC BLOCK SIGNALLING OF A DC

Introduction

In the process of maintenance, adjustment and the current process of operation, there is a need to use knowledge in the field of the functioning of technical means. This is especially true for railroad automation systems (RAS), which is associated with the need to operate at a high level of reliability indicators [1]. For such systems, current operation considers the minimal impact of negative factors on overall operability. The probability of failure, in which there is a decrease in trains capacity at railroad, should be minimized. Reducing the downtime of railway automation systems is achieved by reducing the time intervals from the time the failure occurs until the working state is restored. The key role in this case is played by the skills of the maintenance staff about the work of a particular railroad automation system.

This article describes the development of automatic block signaling (ABS) position of the pulse-wire automatic interlock (AI) direct current (DC). Emulator are designed to improve the skills of the maintenance staff, as well as to simplify the visualization and training of the specialty of this direction.

To form an emulator, it is necessary to form logical connections, take into account the necessary traffic safety requirements for RAS systems, develop an interface of interaction between the operator and logical connections, provide the necessary indications, for technical implementation take into account the hardware requirements, which operates an emulator.

Logical connections

The interaction of traffic control equipment with a locomotive driver is carried out by a system based on logical connections [2]. They provide for the possibility of switching signals on the traffic lights of automatic blocking (ABS) and locomotive lights (cab signals) of locomotive signaling. In logical connections, security conditions are checked, including possible malfunctions on road traffic lights of ABS [2, 3]. To implement the emulator, the logic of the three-arranged automatic block signaling operations is used:

$$
\begin{gathered}
Gr_{\mathrm{i}} = x_{\mathrm{i}} \cap x_{\mathrm{i+1}}, \\
Y_{\mathrm{i}} = x_{\mathrm{i}} \cap \overline{x}_{\mathrm{i+1}} \cap y_{i+1}, \\
R_{\mathrm{i}} = \overline{x}_{\mathrm{i}} \cup \left(x_{\mathrm{i}} \cap \overline{x}_{\mathrm{i+1}} \cap \overline{y}_{\mathrm{i+1}} \right).
\end{gathered} \tag{1}
$$

In logical expressions, variables are used to control the signals of green (Gr_{i}), yellow (Y_{i}) and red (R_{i}) lights on track lights. The switching-on of these signals is mutually exclusive. The variables given in formula (1) take into account:

– the state of occupying or unblocked of track sections behind each track light (variable x_{i}) for which the signal will be switched on;

– the busy or free status of the second block of the track behind each traffic light (variable $x_{\mathrm{i+1}}$) for which the signal will be switched on;

– state of serviceability or malfunction of the red-light lamp on the next passing traffic light (variable $y_{\mathrm{i+1}}$).

In the process of analyzing the logical connections of pulse-wire ABS, the addition of logical expressions executed for signal management to introduce the high-probability fault functions. They occur when isolating joints are shunted or when the lamps of green or yellow lights fail. Simulation of this fault should control the inclusion of a more prohibitive indication on the fencing traffic lights at ABS position. The principle of signal switching and logical connection control takes into account the need to include the following signals for the indicated faults: the burnout of green or yellow lights filament at the next traffic light (number "$i+1$") should lead to the inclusion of a yellow light appearance on the current track light (number "i"); shunting of insulating joints at any traffic light initiates the appearance of false employment of a section of the road and, accordingly, the inclusion of a red light on the traffic light.

Logical connections that are implemented in the emulator are listed below:

$$Gr_{\mathrm{i}} = x_{\mathrm{i}} \cap x_{\mathrm{i+1}} \cap z_{\mathrm{i+1}} \cap w_{\mathrm{i}} \cap w_{\mathrm{i+1}} \cap w_{\mathrm{i+2}},$$
$$Y_{\mathrm{i}} = x_{\mathrm{i}} \cap \overline{x}_{\mathrm{i+1}} \cap y_{i+1} \cap w_{\mathrm{i}} \cap w_{\mathrm{i+1}} \cup$$
$$\cup x_{\mathrm{i}} \cap x_{\mathrm{i+1}} \cap \overline{z}_{\mathrm{i+1}} \cap w_{\mathrm{i}} \cap w_{\mathrm{i+1}} \cap w_{\mathrm{i+2}} \cup$$
$$\cup x_{\mathrm{i}} \cap x_{\mathrm{i+1}} \cap y_{\mathrm{i+1}} \cap w_{\mathrm{i}} \cap w_{\mathrm{i+1}} \cap \overline{w}_{\mathrm{i+2}},$$
$$R_{\mathrm{i}} = \overline{x}_{\mathrm{i}} \cup \left(x_{\mathrm{i}} \cap \overline{x}_{\mathrm{i+1}} \cap \overline{y}_{\mathrm{i+1}}\right) \cup \overline{w}_{\mathrm{i}} \cup \overline{w}_{\mathrm{i+1}}. \quad (2)$$

In the formula (2), variables w_{i}, $w_{\mathrm{i+1}}$ and $w_{\mathrm{i+2}}$ indicates the state of shunted of the insulating joints near the current, next passing track light and traffic lights through 1 ABS position. Inverse states contain information about the malfunction of these elements [2].

Due to the fact that two abutting sections of the track are fixed during the shunting of the insulating joints when checking the two sections, it is necessary to control the state of the equipment of three ahead ABS positions for switching on green light. The yellow signal light is activated when one of the following block sections of the railroad is free, while the second section behind it is monitored as occupied by train or obstructed, the red-light lamp and the insulating joints of this and the next ABS positions are serviceable. The second component of formula (2) with the inclusion of yellow light corresponds to the freedom of two block sections of the path behind the given position with the filament of the permittable lamp (green or yellow) of the subsequent ABS position after this is defected. The third component of the formula with the switching on of a yellow light corresponds to the freedom of two sections behind the current ABS position $(i+2)$ within the event of insulating joints failure. The red light according to logical connections is activated if the next or current traffic joints is malfunctioning, if the next section of the path is occupied by the train, or when red light is transferred from a subsequent traffic light the event of a red-light failure.

In the case of realizing these logical connections by the emulator, it is necessary to take into account that for other sets of logical variables, the lamp lights on the track lights should be switched off. In this case, the lights on the dependent traffic lights include more prohibitive indications.

The algorithm for the operation of one alarm system AB includes the construction of a cascade system for transmitting information from the forward-positioned traffic light equipment, part of which must be implemented additionally. Logical connections for track lights in front and behind this use the original data according to formula (2), but the display of their work is limited by the conditions of the emulator.

Using the logical connections for work emulation

The implementation of the emulator can be realized in various software environments. Considering the perspective of inclusion in the program algorithm of hardware elements, the Lab-VIEW development environment was used [4]. It has the ability not only to connect hardware elements (analog-digital and digital-to-analog converters ADC, DAC), but also simplifies the work on the programming of interface modules and interaction elements.

In this development environment, logical connections are made to include signaling indications of traffic lights according to the formula (2). For this implementation, we took into account the coordination with the corresponding apparatus near the next standing track lights. Due to the fact that the equipment for one signal point will be developed in the emulator, it is necessary to provide additional components of the general scheme [5-7]. They include:

– the equipment of two adjacent traffic lights – to track the dependence of signals on neighboring traffic lights;

– elements for changing the state of the empty objects (block sections of the railway track) – to simulate changes in the starting situation in the presence of a train or the introduction of malfunctions of the circuit of rail chains;

– elements of changing the state of lamp lilaments and insulating joints – to introduce malfunctions into the emulator at an random time interval.

Proceeding from the listed component of elements of the general scheme of the emulator, it is necessary to consider the changes in the logical connections that will correspond to the present scheme of the simulator. Thus, it is necessary to make changes in the logical connections for the automatic block signaling position under study: due to the lack of a diagram of the second ABS position for the researched in the direction of movement, logical variables are excluded that correspond to the inadequacies of the missing equipment on the circuit. Logical relationships for the investigated ABS position are expressed in the following formula:

$$\begin{aligned} Gr_{\mathrm{i}} &= x_{\mathrm{i}} \cap x_{\mathrm{i+1}} \cap z_{\mathrm{i+1}} \cap w_{\mathrm{i}} \cap w_{\mathrm{i+1}}, \\ Y_{\mathrm{i}} &= x_{\mathrm{i}} \cap \overline{x}_{\mathrm{i+1}} \cap y_{i+1} \cap w_{\mathrm{i}} \cap w_{\mathrm{i+1}} \cup \\ &\cup x_{\mathrm{i}} \cap x_{\mathrm{i+1}} \cap \overline{z}_{\mathrm{i+1}} \cap w_{\mathrm{i}} \cap w_{\mathrm{i+1}}, \\ R_{\mathrm{i}} &= \overline{x}_{\mathrm{i}} \cup \left(x_{\mathrm{i}} \cap \overline{x}_{\mathrm{i+1}} \cap \overline{y}_{\mathrm{i+1}} \right) \cup \overline{w}_{\mathrm{i}} \cup \overline{w}_{\mathrm{i+1}} \end{aligned} \quad (3)$$

As can be seen from the formula (3), when the yellow light is on, there is no state in which the insufficiency of the isolating joints of the second traffic light beyond the current one is monitored.

Similarly, for the equipment of adjacent traffic lights, the inclusion of signals corresponds to the expressions (4) – for the next standing ABS position, and (5) – for the traffic light equipment before the current in the course of the sequence.

$$\begin{aligned} Gr_{\mathrm{i}} &= x_{\mathrm{i}} \cap z_{\mathrm{i+1}} \cap w_{\mathrm{i}}, \\ R_{\mathrm{i}} &= \overline{x}_{\mathrm{i}} \cup \overline{w}_{\mathrm{i}}. \end{aligned} \quad (4)$$

Due to the absence of the second light after the test, there is no possibility of simulating yellow fire.

$$\begin{aligned} Gr_{\mathrm{i}} &= x_{\mathrm{i}} \cap x_{\mathrm{i+1}} \cap z_{\mathrm{i+1}} \cap w_{\mathrm{i+1}} \cap w_{\mathrm{i+2}}, \\ Y_{\mathrm{i}} &= x_{\mathrm{i}} \cap \overline{x}_{\mathrm{i+1}} \cap y_{i+1} \cap w_{\mathrm{i+1}} \cup \\ &\cup x_{\mathrm{i}} \cap x_{\mathrm{i+1}} \cap \overline{z}_{\mathrm{i+1}} \cap w_{\mathrm{i+1}} \cap w_{\mathrm{i+2}} \cup \\ &\cup x_{\mathrm{i}} \cap x_{\mathrm{i+1}} \cap y_{\mathrm{i+1}} \cap w_{\mathrm{i+1}} \cap \overline{w}_{\mathrm{i+2}}, \\ R_{\mathrm{i}} &= \overline{x}_{\mathrm{i}} \cup \left(x_{\mathrm{i}} \cap \overline{x}_{\mathrm{i+1}} \cap \overline{y}_{\mathrm{i+1}} \right) \cup \overline{w}_{\mathrm{i+1}}. \end{aligned} \quad (5)$$

According to the formula (5), when lamp lights are switched on at the current traffic light, the possible malfunction of the insulating joints of the current traffic light is not taken into account.

Due to the fact that the switching on of lights on each position considers only a certain set of input logic variables, if the set of input signals are not matched, it is necessary to switch on an additional signal. In real ABS scheme when occurs malfunctions into the scheme of lamps filament, when the power lines of the traffic light are cut off, the lights are switched off on traffic light. According to the traffic regulations when the traffic lights are switched off, the locomotive's driver needs to slow down and stop. Further movement is possible only upon obtaining permission. This ensures compliance with the safety of train traffic. Therefore, in the emulator it is provided to turn off the signal indication when the permissible set of variables is not-coincident (built-in protection of signal mismatch) or in case of malfunctions of the current signal filaments.

Data input for program emulator development

The implementation of the software product is associated with the need for the operator to interact with the goal of inputting the initial data for the inclusion of indicators and an adequate study of the operation of the object - the signal point of the auto-lock. To such data it is necessary to carry carried logical variables, corresponding to the flight situation and malfunctions.

Considering the above logical connections, it is necessary to input next data:

– the state of the two sections of the path behind this position in the course of movement, and one in before of it;

– the state of the filaments of the lamps of the three traffic lights, for simplicity of the interface, the introduced fault is actual for this indication, which simplifies the input of the values of the variables y_{i+1} and $z_{\mathrm{i+1}}$. The emulator should automatically recognize the information about the lamp filament failure - for prohibiting or permissive signal;

– the state of insulating joints of the current and ahead of the traffic light.

On the basis of the input data, according to logical connections, signals of traffic lights should be activated and indications of the operation of intermediate circuits should be displayed. To such schemes of a ABS position includes:

– pulsed rail circuits of DC [8], indicators – transmitter at the supply end, pulse receiver and decoder at the relay end;

– linear circuits, indicators – for displaying the status of linear and signal relays;

– schemes for switching on the lamps of green, yellow and red lights – to display the activated signal and the state of the filament lamps;

– additional information accompanying schemes corresponding to relay-contact ABS circuits.

Based on the initial data and the required indication of the operation of the signal points, an interface has been developed for interact between the computer program and the operator.

Emulator interface

For the correct display of the indication and input of information on the state of logical variables, during developing the interface used the schemes of the ABS position (see Figure 1).

In the window of the program-emulator there are shown schematic diagrams of the pulsed-wire ABS position of a AC. Presents:

– scheme of track circuits (supply and relay ends of adjacent block sections of the track), used for monitoring block sections;

– scheme of linear circuits (executive and control parts of adjacent lines);

– scheme for switching on the signals in researched ABS position with the filament light control relay;

– scheme for selecting the locomotive CAB signaling lights;

– indicators of traffic lights, transmitters, pulse and track relay, line, signal and filament lamp control relays, indicators of pressing the buttons of input malfunctions;

– buttons for inputting necessary information of the status of occupied/free block, faults of traffic filament lights and insulating joints.

In the dynamic mode, the state of the relay contacts changes according to the power state on their windings. Thus, the perception of the operation of the electrical circuit of the signal point is simplified, it is possible to trace the currents of the electrical circuits that flow in the circuit.

Indicators of the traffic lights give color values according to signals of traffic lights (red, yellow and green lights with the working state of the lamps, gray – in case of a malfunction, when the lamp filament failure). For the relay state, the indicators provide information of the following type:

– for transmitter and neutral: red – no power, green – power is present;

– for combined linear relay: red – no power, yellow – reverse polarity current supply, green – current supply of direct polarity;

– for the buttons for entering the track information: gray color – the button is not pressed, the path is clear / the lamp is OK / the isolating joint is OK; when entering a busy path state, the button's color is red; when entering information about the lamp filament failure – yellow; if the insulating joint is faulty – the brown color of the corresponding button.

More detailed information about the work of the emulator is obtained by analyzing the functional dependencies with the interaction through the interface.

Functional interaction of emulator

The implementation of the emulator is based on the logical connections that are given above. The executed algorithms consider the receipt of primary information as input logic variables, the conversion of these data to find signals when switching on intermediate circuits (track circuits, linear relays), the inclusion of signals on track light signals and the final transmission of logic signals between ABS position in the opposite direction to the movement.

The interface of the emulator program makes it possible to evaluate only the result of the operation of the ABS position circuit, but not the functional interaction between the nodes of the equipment. The principle of the emulator and the interaction of internal nodes implements a block diagram on which the interconnection and functional transformations between variables and input-output elements are formed. Due to the fact that different logical connections are used for each of the ABS position, individual functional connections have been developed for each of them. An example of a block diagram for 3 and 5 traffic lights is shown in Fig. 2.

Logical input variables are shown to the left with outgoing data lines to the right, indicators of signals of traffic lights and other elements are on the right. They have a name similar to the elements of the interface. All transformations according to formulas (3)–(5) are performed by internal function blocks and color control blocks with the names of the output elements.

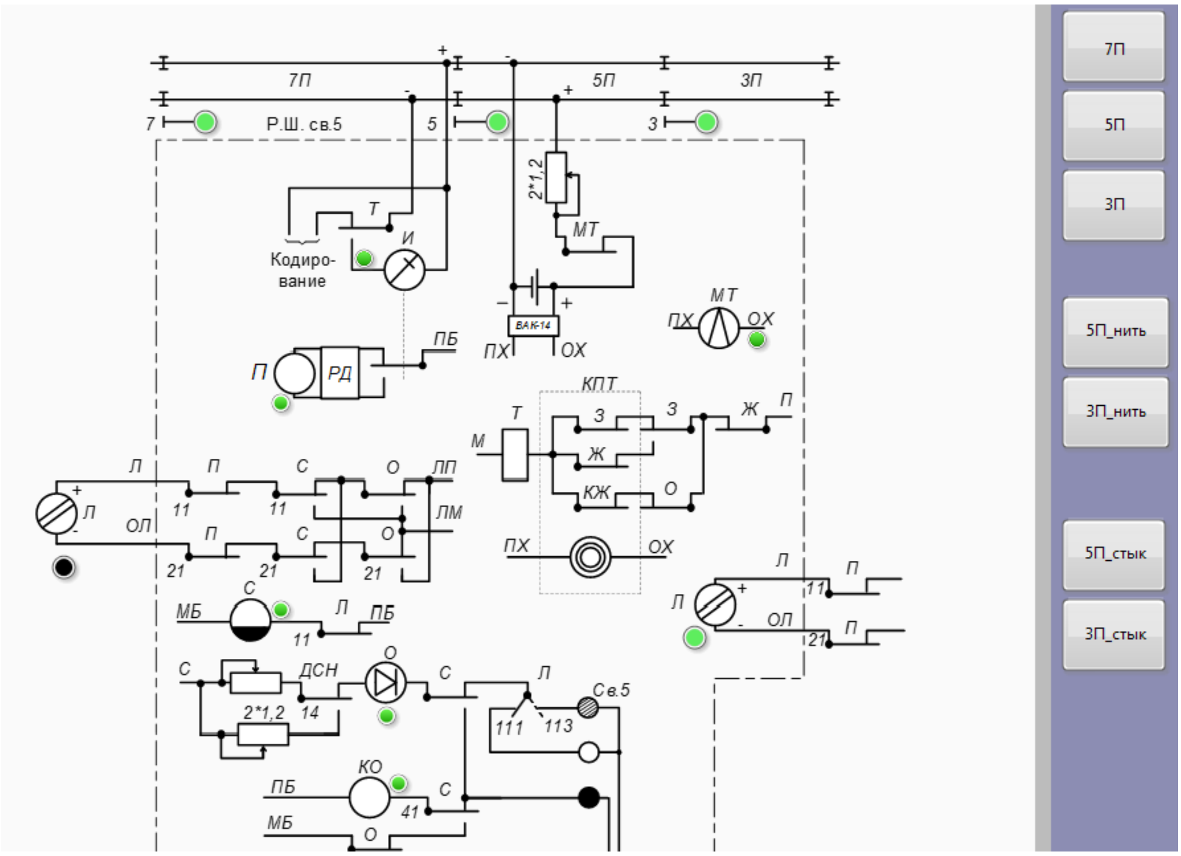

Fig. 1. The window of the program-emulator of pulse-wire ABS position

The transmission of information between the ABS positions is carried out using variables in various areas of the block diagrams. For example, the value of a variable that indicates the state of the first block section behind the current traffic light is simultaneously used as a variable for the previous traffic light. For this block diagram, this variable is 5P, which is considered both for the traffic light 5 or for the traffic light 7.

In Fig. 2 in the above fragment there is no control scheme for the MT transmitter, which considers the duration of the intervals and power pulses. For artificial sampling, 10 ms timings are used (on the diagram called “Time Delay”).

The dynamics of the circuit is realized by changing the position of the contacts according to the power state on each of the relays. An example of the implementation of the change in contacts for a neutral and polarized relay (part of a combined relay Л) is shown in Fig. 3 and 4.

The status of the relay depends on the type, and the indications include: for a neutral relay – under current or has no power; for a polarized relay – the relay has no power, under reverse polarity current, under current of direct polarity. An example of the relay status indication is shown in Fig. 5.

The traffic light signal corresponds to the transmitted information according to the travel situation and the state of the equipment, as described above by logical connections. The visible signals are given on the example of a traffic light 5.

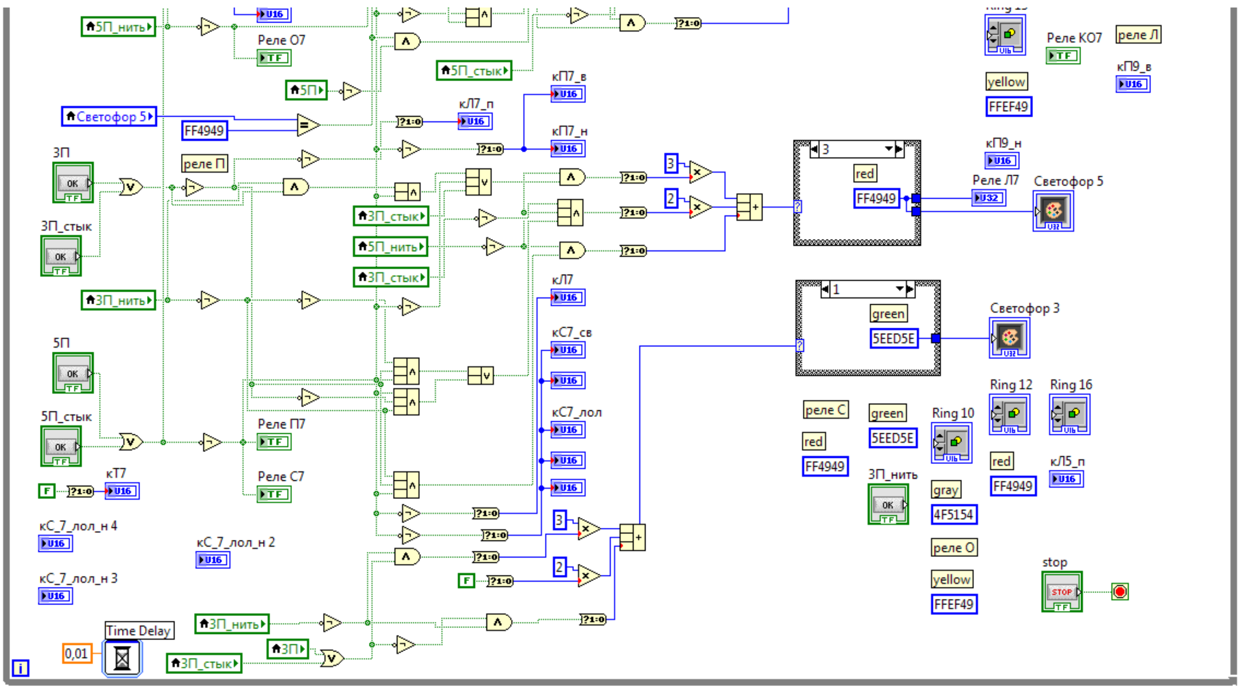

Fig. 2. Fragment of the block diagram of the emulator

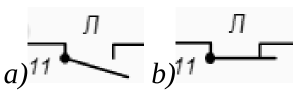

Fig. 3. The state of connected *(a)* and disconnected *(b)* neutral contacts

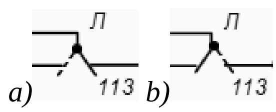

Fig. 4. The state of connected contacts of the reverse *(a)* and straight *(b)* polarities

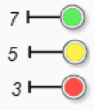

Fig. 5. Traffic signals

Functional interactions are implemented by internal elements of the block diagram of software environment. A detailed description of each function block for implementing the specified functions is described in the sources [9]. This implementation device is an object without memory, in which the state of the outputs depends only on a set of input values [10]. The discretization of the nonlinear or continuous elements of the circuit is realized to simplify the operation of the track circuits and does not affect the perception of the performance of the circuit as a whole. Full guidance on working with the software is given in the operation manual. It considers possible variants of input effects and the result in the form of an indication.

Hardware requirements

The use of the software product provides for the presence of a virtual machine [11] for displaying the interface of interaction with a person, the implementation of logical dependencies and the functional operation of internal nodes. To correctly display the information of this emulator, you must have a 64-bit operating system of the Windows XP (SP3) / 7/8/10 family, a processor: at least Intel Pentium with a clock frequency of 2.7 Hz; at least 4 GB of RAM (for Windows XP – at least 2 GB); the amount of storage for installation is at least 700 MB, and for storing installation files - at least 300 MB (including a virtual machine); monitor with a resolution of at least 1280×800 pixels; keyboard and computer mouse.

Conclusions

As a result of the development, an emulator has been completely formed for analyzing the operation of the signaling system of automatic blocking of DC with pulse-wire rail circuits. Based on the generated and improved work algorithms, the interface of the emulator program is developed and implemented. For him, dynamic visual elements are displayed, displaying all the necessary switching of relay contacts, signals of traffic lights. In addition, to receive information on the status of the relay, the neutral and polarized relay types of the relay are used. In the future, this principle of developing an emulator can be used to build more complex circuits, not only automatic block signaling, but also electric centralized interlocking control, dispatcher interlocking controlled signals etc.

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Ключові слова: автоматичне блокування, рейкове коло, програмний емулятор, логічні зв’язки.

Ключевые слова: автоматическая блокировка, рельсовая цепь, программный эмулятор, логические связи.

Keywords: automatic block signaling, track circuit, programming emulator, logical connectivity.

Reviewers:
D. Sc. (Tech.), Prof. A. M. Mukha,
D. Sc. (Phys. and Math.), Prof. V. I. Havryliuk.

Received 13.11.2018.
Accepted 27.11.2018.