Virtual Laboratory Stand
«Relay-Contactor Circuits for Electric Drive Control»

Brief User Manual

General Description of the Software Product

Electric drives powered by a network with a constant voltage are widely used in all industries. Such electric drives are controlled by relay-contactor equipment. The term «relay-contactor control systems» (RCCS) refers to logical control systems built on a relay-contactor element base and designed to automate the operation of engines. With the help of RCCS, the following operations are automated: turning the engine on and off; choice of direction and speed of rotation; engine starting and braking; creating temporary delays in movement; protective shutdown of the engine and stop of the rotation mechanism. These operations are necessary to perform the movement of the working body of the mechanism according to given technological conditions.

The virtual laboratory stand «Relay-Contactor Circuits for Electric Drive Control» is intended for simulation training in the principles of constructing relay-contactor control circuits for a three-phase asynchronous electric drive using standard electrical components – circuit breakers, contactors, relays, push-button posts, etc.

Main functions of the software product:

- Construction and editing of a schematic diagram of an electrical circuit;
- Construction and editing of a simulation model of a laboratory stand;
- Software simulation of an assembled electrical circuit with the ability to interactively change the state of devices;
- Simulated measurement of voltage in a circuit using a virtual multimeter;
- Working with user project files;
- Interaction with a physical relay board to implement software control of the electric drive (optional).

The software product is implemented as a two-dimensional graphical application using the OpenGL 2.0 component base.

Basic system requirements for a personal computer:

- Central processor clock frequency: at least 3 GHz;
- RAM: at least 4 GB;
- Video memory: at least 512 MB;
- Screen resolution: no less than 1024x768x32;
- Support for OpenGL version 2.0 (or Vulkan);
- Standard keyboard and computer mouse with scroll wheel;
- Sound reproduction means (speakers or headphones).

The graphical user interface of the software product is implemented in English and Chinese.

User Interface Description

The main window of the software product is divided into four areas: 1 – tool bar, 2 – list of components, 3 – work area (drawing), 4 – status bar (Figure 1).

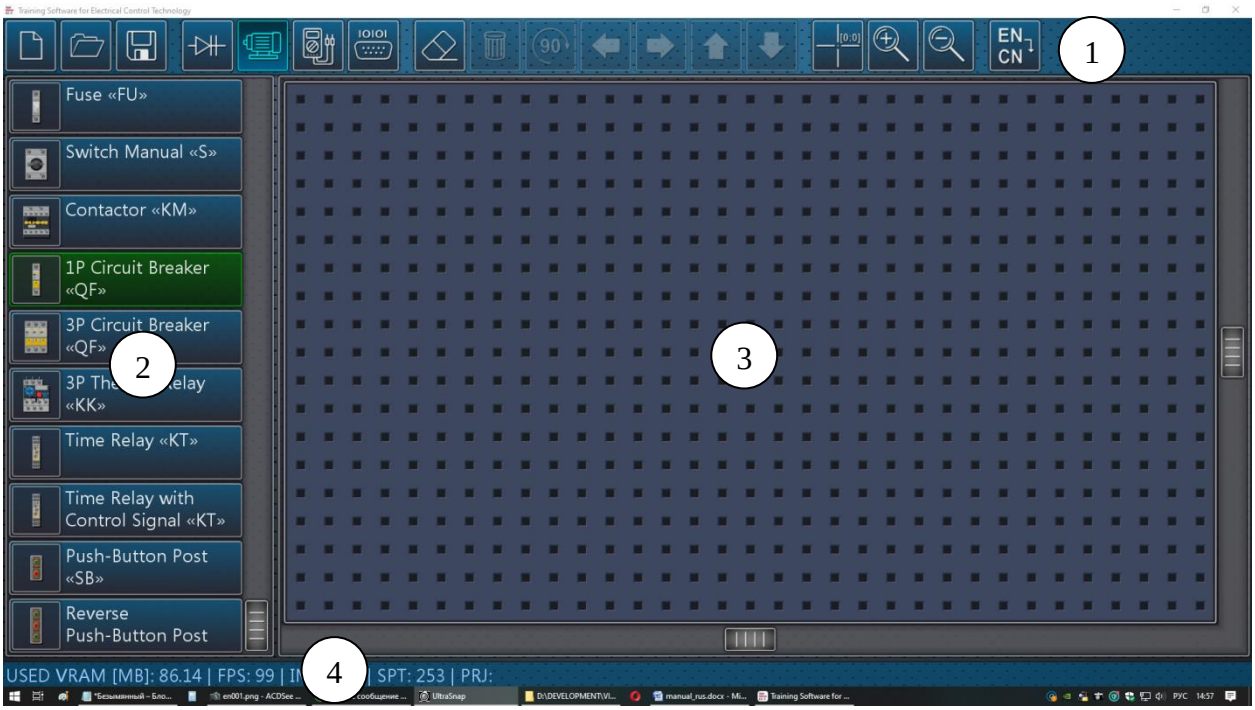


Figure 1 – Elements of the Program Main Window

The tool bar, located at the top of the screen, includes several groups of buttons (in order from left to right):

– buttons for file operations: create/open/save;

– buttons for switching program modes: circuit diagram editor/simulation model editor/simulation mode/physical equipment control mode;

– buttons for controlling circuit elements (or simulation model objects): delete all objects/delete the selected object/rotate an object/shift an object in one of four directions;

– drawing (or simulation model) control buttons: center the drawing/zoom in/zoom out;

– button to switch the language of the graphical user interface.

The program can only work in one of four modes: circuit diagram editor, simulation model editor, simulation mode, physical equipment control mode.

When the mouse hovers over the tool bar buttons at the bottom of the window, a text prompt is displayed on the status bar.

Note: project file paths must be specified in Latin characters.

Circuit Diagram Editor Mode

In the schematic diagram editor mode, the working area of the screen is represented by a point coordinate field (Figure 2). In this mode, the list of components located on the left side of the screen includes elements of the electrical circuit diagram. To add an element to a drawing, you need to drag its pictogram from the list to the work area.

The list of components and the workspace have scrollbars, which are interacted with by dragging the slider. When the mouse hovers over the list of components, the list can be scrolled by rotating the mouse wheel.

You can also manipulate the drawing directly using the mouse. Pressing and holding the right mouse button while moving the mouse pointer within the work area scrolls the drawing in the vertical and horizontal directions. Rotating the mouse wheel allows you to change the scale of the drawing.

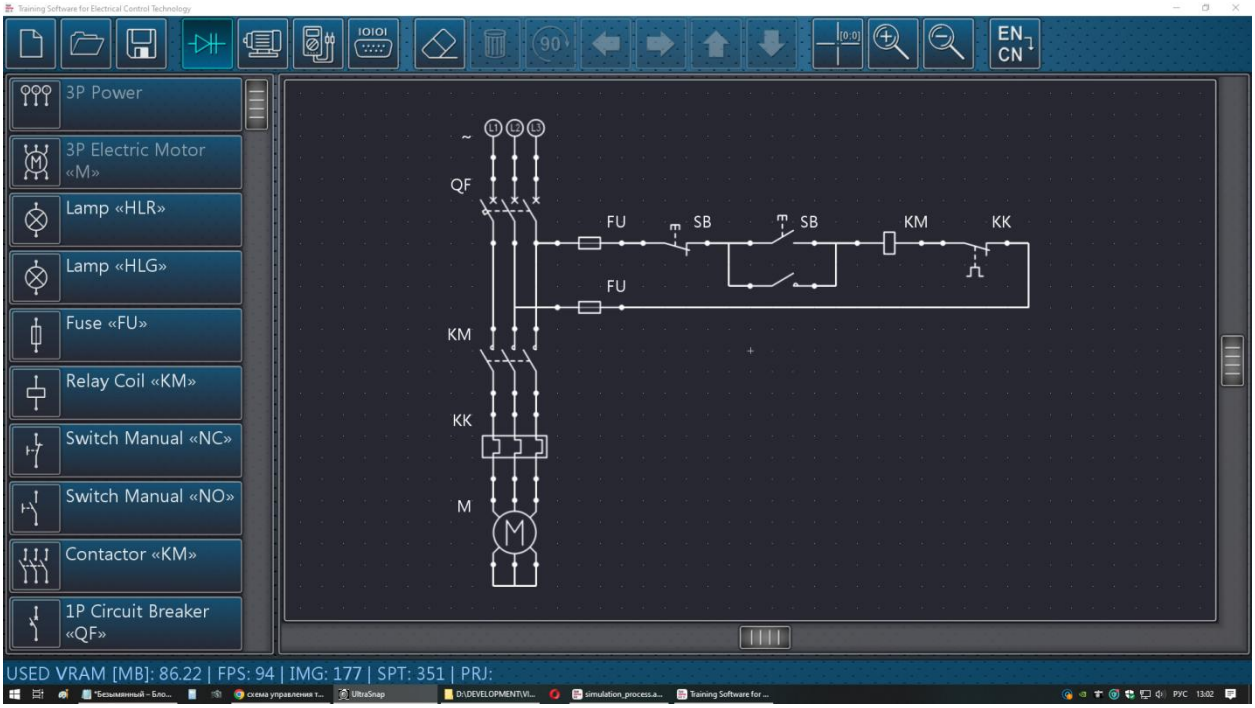
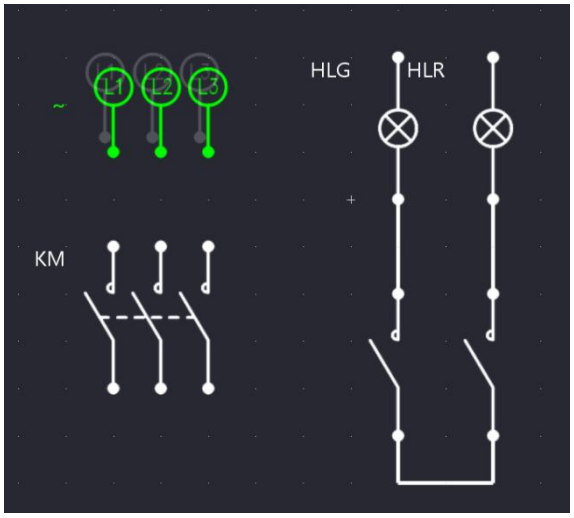


Figure 2 – View of the Program Main Window in Circuit Diagram Editor Mode

While dragging an element, it is automatically snapped to the coordinate grid of the workspace. If the grid nodes overlapped by the moved element are not occupied by another element, the element pictogram turns green (Figure 3.a). Otherwise, the element pictogram turns red and the element cannot be placed on the drawing.

a 

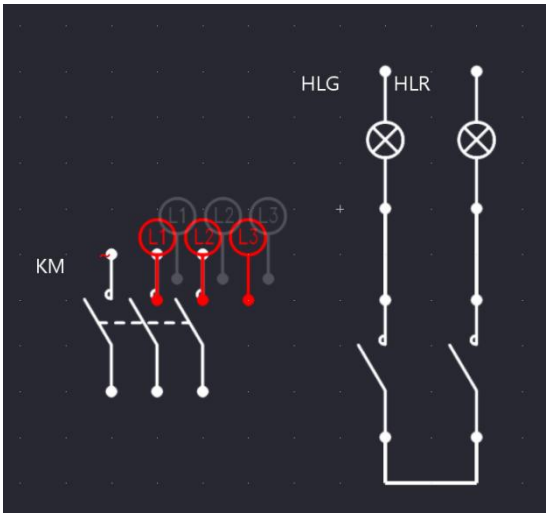
b 

Figure 3 – View of the Moved Element Pictogram

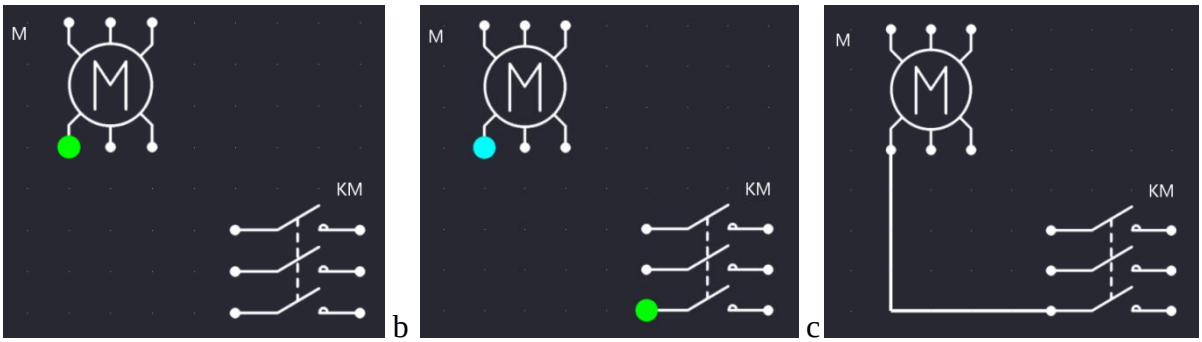
If the mouse button is released while moving an element while the element pictogram is highlighted in green, the element will be added to the drawing. If the mouse button is released while the element's pictogram is highlighted in red, the element will be returned to the list.

A simultaneous single click of the right mouse button while moving an element causes the element icon to rotate clockwise.

An element placed on a drawing can be moved to a new position. Selecting an element placed on the drawing is carried out by a single click with the left mouse button. Manipulation of the selected element can also be performed using the corresponding buttons on the toolbar (Figure 4).

Figure 4 – Buttons for Controlling Circuit Elements

The pictogram of each element has contact points. To create connections between elements, you must sequentially select two contact points between which a connection will be established (Figure 5).

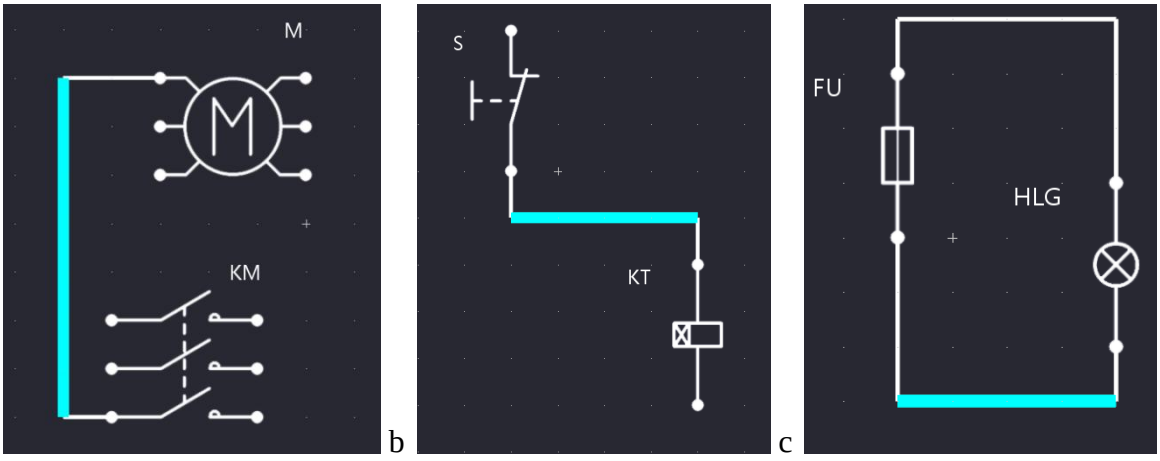


a b c

Figure 5 – Sequence of Adding a Connection Between Contact Points: Selecting the First Contact Point (a), Selecting the Second Contact Point (b), Establishing a Connection (c)

Deleting an existing connection is done by reselecting two contact points.

When you move an element that has connections with other elements, the connection lines are rebuilt automatically. When you delete an element, its links are also deleted.



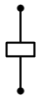
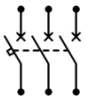
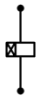
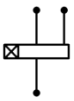
a b c

Figure 6 – Selecting a Communication Line for Further Displacement

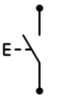
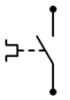
Connection lines with more than two straight sections can be edited using the mouse. When you hover the mouse over a connection section that can be displaced, this section is highlighted in color (Figure 6).

Constructing a schematic diagram of an electrical circuit is the primary learning task. It is recommended that further assembly of the laboratory stand simulation model be carried out on the basis of the compiled circuit diagram. The list of elements available for drawing up a circuit diagram is presented in Table 1.

Table 1 – The Main Elements of the Circuit Diagram

№	Pictogram	Element Name
1	2	3
1		3P Power
2		3P Electric Motor «M»
3		Lamp «HLR»
4		Lamp «HLG»
5		Fuse «FU»
6		Relay Coil «KM»
7		Switch Manual «NC»
8		Switch Manual «NO»
9		Contactor «KM»
10		1P Circuit Breaker «QF»
11		3P Circuit Breaker «QF»
12		3P Thermal Relay «KK»
13		Time Relay «KT»
14		Time Relay with Control Signal «KT»

Continuation of Table 1

1	2	3
15		Contact «NO»
16		Contact «NC»
17		Contact Switch-On Delay «NC»
18		Contact Switch-On Delay «NO»
19		Contact Switch-Off Delay «NC»
20		Contact Switch-Off Delay «NO»
21		Automatic Return Button «NC»
22		Automatic Return Button «NO»
23		Thermal Relay Contact «NO»
24		Thermal Relay Contact «NC»

Simulation Model Editor Mode

In the simulation model editor mode, the user assembles a laboratory stand, operating with objects – relay-contactor equipment devices. In this mode, the coordinate field of the screen's working area is replaced by a background image of the mounting panel on which the main devices are installed (Figure 7).

The principle of adding and moving objects in a workspace field is similar to the circuit diagram editor, except that objects cannot be rotated.

Connections between contact points of devices are represented as flexible wires with the ability to edit their shape. Each wire is represented as a Bezier spline with two guides at the start and end points. To select a wire, you need to hover the mouse pointer over it and single-click with the left mouse button. In this case, the spline guides and their control points will be displayed on the screen (Figure 8). To change the shape of a spline, you need to move the control point of the spline guide with the mouse. When selected with the mouse, the control point and spline guide are colored orange. If an object is deleted, its connections are also deleted.

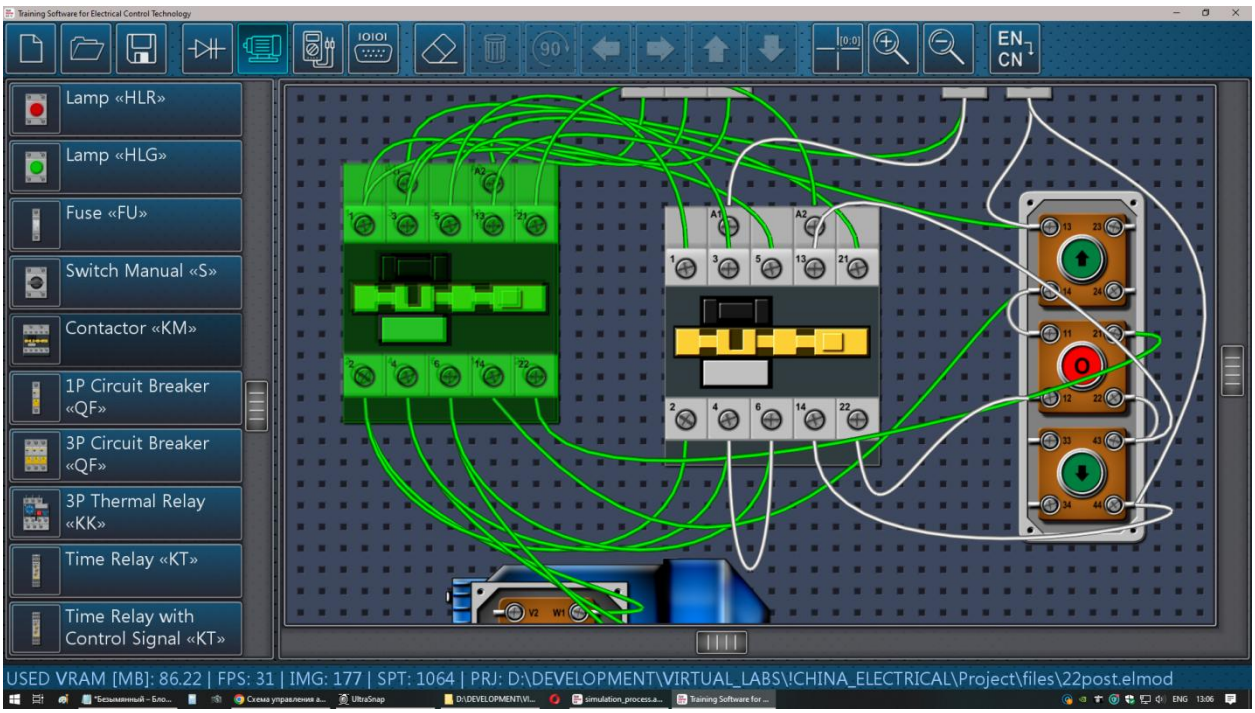


Figure 7 – View of the Program Main Window in the Simulation Model Editor Mode

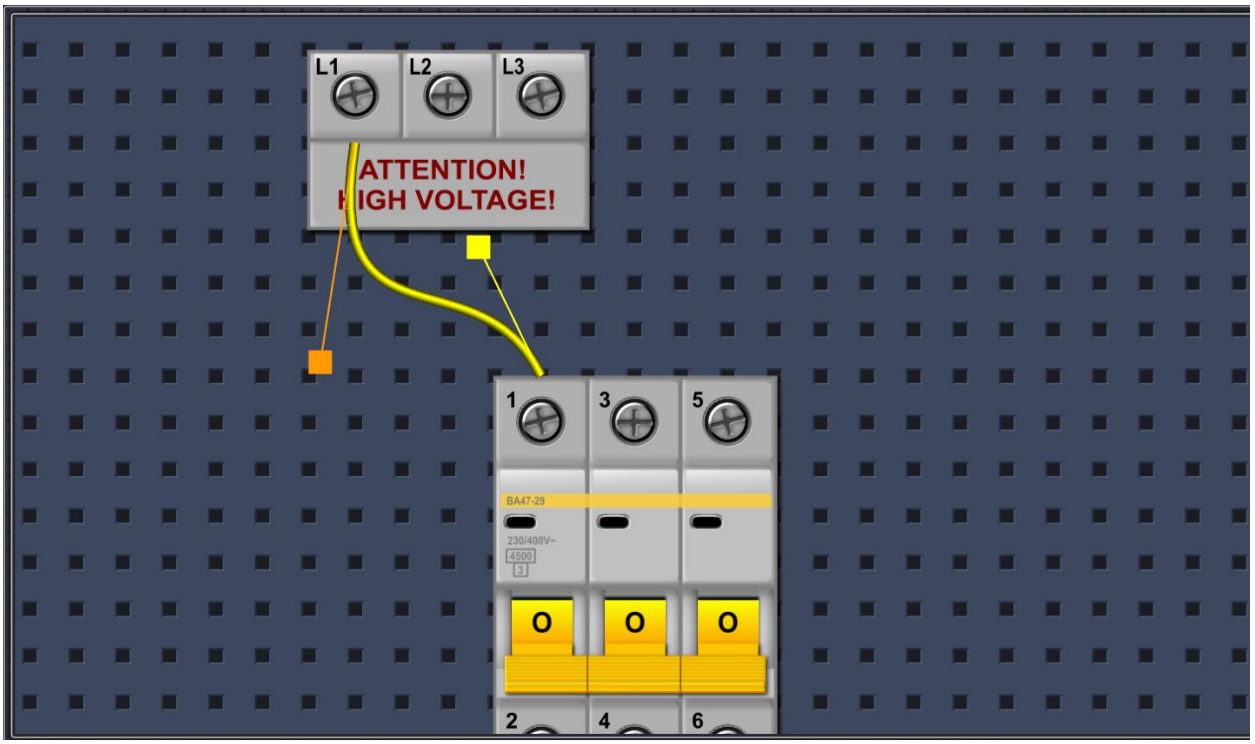
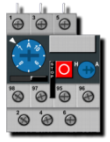


Figure 8 – Bezier Spline Guides for Editing the Shape of Wires

In the simulation model editor mode, all objects are presented in a passive (off) state. The user can assemble power circuits and electric motor control circuits using standard devices.

Only one power source and only one electric motor can be added to the model. The remaining components of the circuit can be used in unlimited quantities. The list of components available for the simulation model is presented in Table 2.

Table 2 – Main Components of the Simulation Model

№	Pictogram	Component Name
1	2	3
1		3P Power
2		3P Electric Motor «M»
3		Lamp «HLR»
4		Lamp «HLG»
5		Fuse «FU»
6		Switch Manual «S»
7		Contactor «KM»
8		1P Circuit Breaker «QF»
9		3P Circuit Breaker «QF»
10		3P Thermal Relay «KK»
11		Time Relay «KT»

Continuation of Table 2

1	2	3
12		Time Relay with Control Signal «KT»
13		Push-Button Post «SB»
14		Reverse Push-Button Post «SB»

Simulation Mode

When switching from the simulation model editor to simulation mode, the editing capabilities of the laboratory stand model are not available. At this stage, an automatic recursive calculation of the electrical circuit from the power source to the electric motor is carried out. The user can interact with the devices – change the position of switches, press buttons, adjust relay modes. In simulation mode, the list of components on the left side of the screen is replaced by an image of a multimeter (Figure 9).

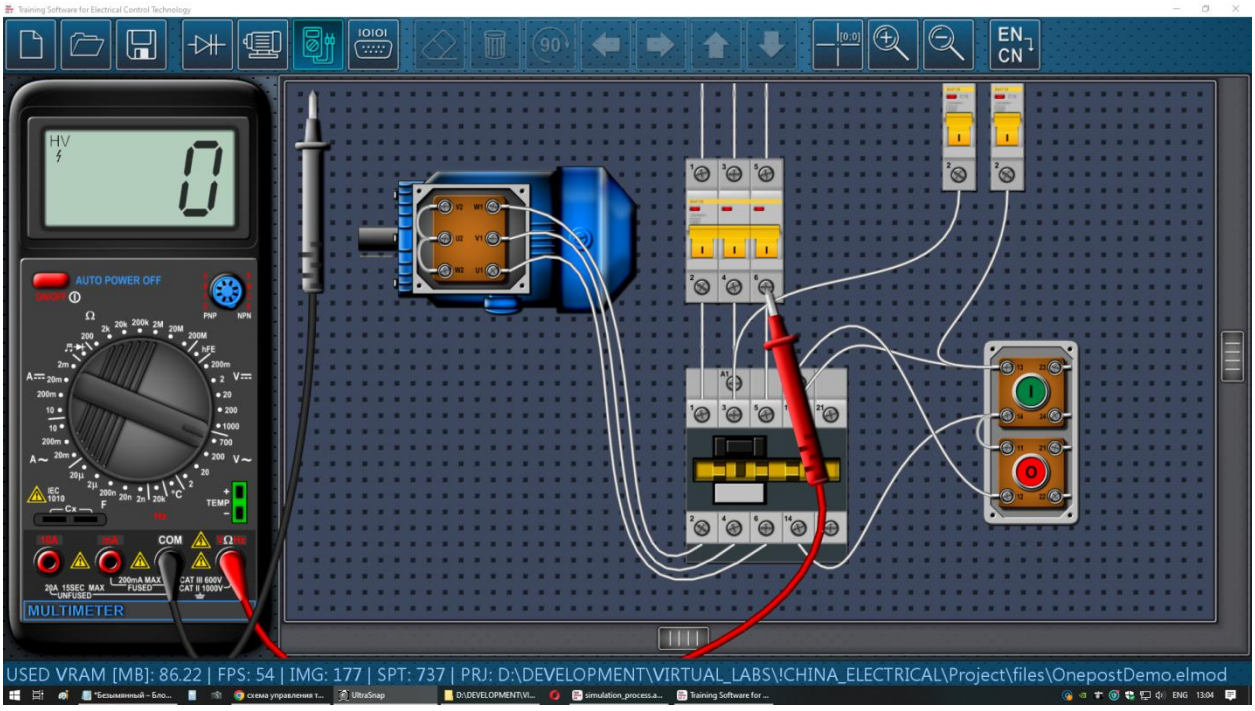


Figure 9 – View of the Program Main Window in Simulation Mode

Measuring probes are located to the right of the multimeter. Each measuring probe can be placed at the measuring point (contact of any device). To move the measuring probe to the measuring point, it is necessary to click sequentially with the left mouse button on the image of the probe, and then on the image of the contact point of the device. To return the measuring

probe to its original position, select it by clicking the left mouse button and click in the free area of the working field.

In the simulation mode, various emergency situations are simulated – short circuits in sections of the circuit, abnormal operating modes of the electric drive, malfunctions in the control circuit, etc.

The main events of the simulation model are accompanied by sound.

Physical Hardware Control Mode

This mode of program operation is optional and requires the presence of special physical laboratory equipment: an 8- or 16-channel relay board (Figure 10), a 12 V power supply and an electric drive.

Figure 10 – Example of an 8-Channel Relay Board with RS232 and USB Communication Interfaces

A serial port is used for software control of the relay. When connecting the relay board to a computer, on the program side, you need to configure the connection parameters. In the «media» subdirectory of the program there is a configuration file «ectpref.ini», which includes the following parameters:

1	current program interface language
7	number of used COM port
115200	bit/sec throughput
n	parity
8	data bits
1	stop bits
127.0.0.1	IP address for internal data exchange on the PC side via UDP protocol

7000	port number for internal data exchange on the PC side via UDP protocol
5000	time for automatic completion of the communication process after the simulator is completed

The COM port number should always match the actual port number in the Windows system settings.

Using the presented software product and a relay board, you can control forward and reverse rotation of a physical motor, connect light indication, etc.

Content