MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL TECHNICAL UNIVERSITY
«KHARKIV POLYTECHNICAL INSTITUTE»

METHODICAL INSTRUCTIONS

for laboratory works

on the discipline "Electric devices"

for foreign students of the academic and scientific institute
of power engineering, electronics and electrical engineering

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INTRODUCTION

This edition is dedicated to expand the theoretical knowledge of foreign students on the «Electric devices» discipline. The objects of study are circuit breaker and electric devices, which are the basis of electric power in various industries and household. The subject of this course is electric devices, which are used in practice to operation to control different electrical networks. After the fulfillment of the laboratory works the student has to know the structure, basic elements, the principle of operation and characteristics of electric devices. The report shall begin with a cover page, where you should write the name of the University, the department of Electrical Apparatus, the topic of the laboratory work, your group, your name, and the name of your lecturer. In the report you should define the problem, specify the input numerical data, provide tables with your experimental data, make specific calculations, plot charts and graphs. At the end of the report student has to make a conclusion of the laboratory work.

Laboratory work 1

MODULAR CIRCUIT-BREAKERS RESEARCH

The purposes: to get acquainted with design and technical characteristics of modular circuit-breakers; determination of the opening time of thermal overload release, determination of the opening time of instantaneous release.

The subject of research: single-pole modular circuit breaker (MCB), overcurrent tripping characteristics type B, rated current I_n = 6 A

Ranges of instantaneous tripping of MCB type B: above $3 \cdot I_n$ up to and including $5 \cdot I_n$.

Task

1. To examine the purpose, principle of operation, design, technical characteristics of the researched MCB and the test stand setup.

2. Determine the opening time of thermal overload release.

3. Determine the opening time of overcurrent release.

4. Build the time-current tripping characteristic of the researched MCB.

General information

Circuit breakers are mechanical switching devices, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short-circuit. They thus also fulfill the requirements of (load) switches. Circuit breakers are often designed so that they can fulfill the requirements for disconnectors.

IEC 60898-1 Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations - Part 1: Circuit breakers for AC operation.

IEC 60947-2 Low-voltage switchgear and controlgear - Part 2: Circuit-breakers.

The IEC 60947 series applies to circuit-breakers, the main contacts of which are intended to be connected to circuits, the rated voltage of which does not exceed 1000 V AC or 1500 V DC.

Release – device, mechanically connected to (or integrated into) a circuit-breaker, which releases the holding means and permits the automatic opening of the circuit-breaker.

Overcurrent release – release which causes a circuit-breaker to open, with or without time-delay, when the current in the release exceeds a pre-determined value.

Overload release – overcurrent release intended for protection against overloads.

Overvoltage – any voltage having a peak value exceeding the corresponding peak value of maximum steady-state voltage at normal operating conditions.

Rated value – stated value of any one of the characteristic quantities that serve to define the working conditions for which the circuit-breaker is designed and built.

Circuit breakers have the capacity to break short-circuits. They are classified according to their breaking capacity, their design and their capability to limit short-circuit currents. They are classified according to the following groups:

– Circuit breakers that clear at current zero;

– Current-limiting circuit breakers.

The devices of both groups can be further subdivided according to design:

– Miniature Circuit Breakers (MCB). Single pole or modular multipole circuit breakers for up to around 100 A rated current for line protection with or without residual current release for installation applications

– Moulded Case Circuit Breakers (MCCB). Circuit breakers with a housing of insulating material that forms an integral part of the circuit breaker (rated currents typically up to around 1600 A)

– Air Circuit Breakers (ACB). Large installation switches with open design (rated currents typically 300 … > 3000 A).

Ranges of instantaneous tripping of MCB type B: above $3 \cdot I_n$ up to and including $5 \cdot I_n$. A current equal to $3 \cdot I_n$ (I_n – rated current) is passed through all poles starting from cold. The opening time shall not be less than 0,1 s. A current equal to 5 In is then passed through all poles, again starting from cold. The circuit-breaker shall trip in a time less than 0,1 s.

Description of the test setup

The experimental research circuit is shown in Fig. 1.

Circuit breaker Q1 is used to supply the AC voltage source to the stationary laboratory table. The indicator HL1 shows the presence of power to the laboratory table. Circuit breaker Q2 (C25) is used to supply the AC voltage source to the mobile laboratory stand. The indicator HL2 shows the presence of power to the mobile laboratory stand.

Switch SA connects the cooling fan M. The laboratory autotransformer T1 regulates the voltage *U* in the primary winding of the transformer T2 and, accordingly, in the secondary winding, where the current is controlled by a Clamp Meters. Thus, the autotransformer makes it possible to set the current in the pole of the studying circuit breaker Q4 (MCB, B6). Circuit breaker Q3 (C63) is used to set the required current value on the tested circuit breaker Q4.

When the required current value is set by the laboratory autotransformer T1, the circuit breaker Q3 is switched off and circuit breaker Q4 is switched on. After the operation of the circuit breaker Q4, the switch SA turns on the fan to cool it.

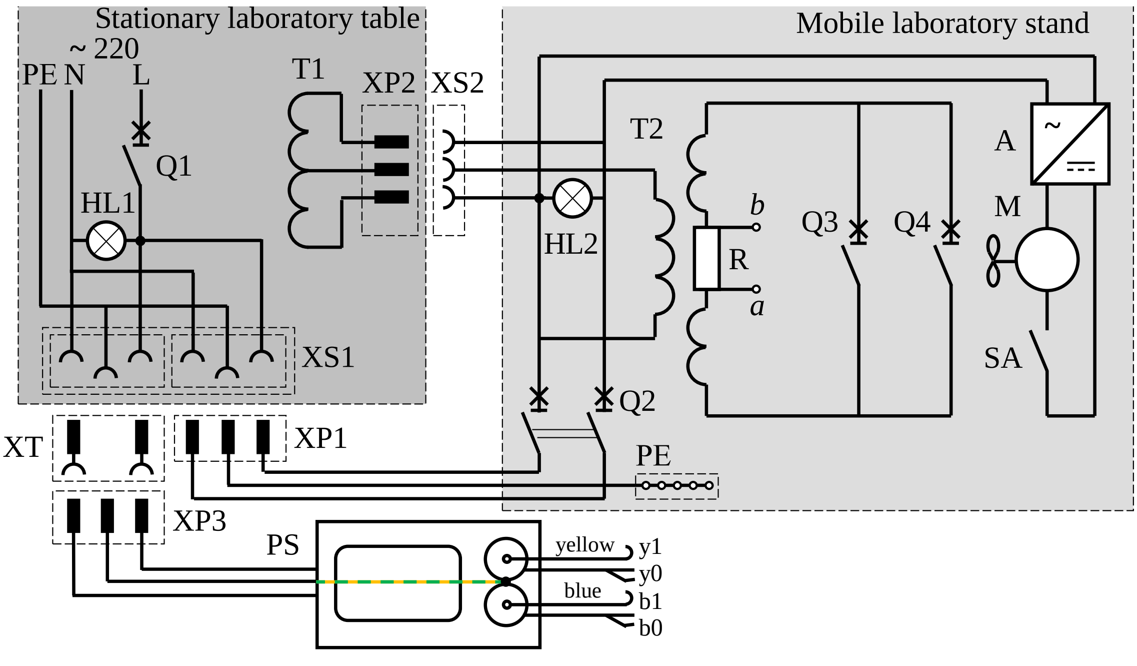

Fig. 1 – The electrical circuit of MCB research

Sequence of laboratory work

Before starting the experiments, you need to perform the operations in the following sequence:

1) Connect X1 to the socket on a stationary laboratory table (laboratory autotransformer T1);

2) Connect X2, X3 to the socket on a stationary laboratory table (power supply of the laboratory stand and oscilloscope);

3) The handle Q1 is set in the upper position – "I";

4) The handle Q2 (C25) is set in the upper position – "I";

5) Connect a Clamp Meters to a special wire loop (measuring up to 400 A) to set and control the current in the circuit;

6) Check that the T1 autotransformer handle is in the zero position:

7) Connect oscilloscope channel CH1 to terminal 4.

Experiment 1

Checking the operating time of the overcurrent releases (instantaneous and overload) when the current values are $I = 1{,}5 \cdot I_n$; $2{,}55 \cdot I_n$; $5 \cdot I_n$:

1) Turn on the oscilloscope.

2) Set the trigger on the oscilloscope to 2 V, 5 V or 10 V, time 1 s.

3) The handle Q3 (C63) is set in the upper position – "I";

4) Using the laboratory autotransformer T1, slowly set the current according Table 1, which is controlled by a Clamp Meters.

5) The handle Q3 (C63) is set in the lower position – "0";

6) The handle Q4 (B6) is set in the upper position – "I";

7) After operating the circuit breaker Q4, the actuator SA is set in the upper position "I" and turned on the fan M.

8) Save the resulting process oscillogram to a USB flash drive.

9) When the overload release is cooled to 25-26 °C, set the actuator SA in the lower position - "0".

10) The experiment is repeated 10 times for each current value, wright down the

value of the tripping time in Table 1.

Table 1 – The operating time of the instantaneous and overload releases

The experiment No.	Current *I*, A		
	9	15	30
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Average value			

Experiment 2

Determination of the operation time of the MCB as a function of the value of current *I*:

1) Turn on the oscilloscope.

2) Set the trigger on the oscilloscope to 2 V, 5 V or 10 V, time 5 ms.

3) The actuator Q3 (C63) is set in the upper position – “I”;

4) Using the laboratory autotransformer T1, slowly set the current I_{Δ} according Table 2, which is controlled by a Clamp Meters.

5) The actuator Q3 (C63) is set in the lower position – “0”

6) The actuator Q4 (B6) is set in the upper position – “I”

7) After operating the circuit breaker, the actuator SA is set in the upper position "I" and turned on the fan M.

8) When the overcurrent release is cooled to 25-26 °C, set the actuator SA in the

lower position - "0".

9) Repeat steps 4-8 the required number of times, wright down the results in Table 2.

Table 2 – MCB tripping time depending on current *I*

I, A		12	15	18	21	24	27	30	33
Tripping time, s	1								
	2								
	3								
	4								
	5								
Average value									

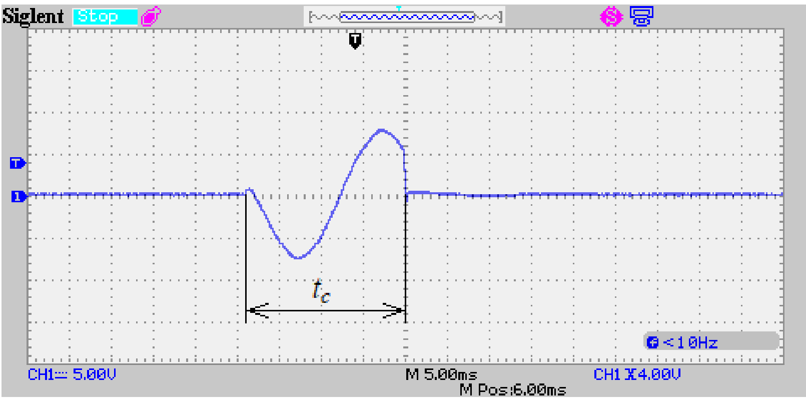

Fig. 2 – Oscillogram of the current in the MCB (tripping time t_{tr})

According to the Table 2 build the functional dependence the average value of the MCB tripping time on the value of current *I*.

The Tables 1, 2 oscillograms and graph must be included in the report.

After conducting experiments, perform the operations in the following sequence:

1) the handle of the autotransformer T1 is rotated counterclockwise until it stops;

2) disconnect and turn off the Clamp Meters;

3) the actuator Q2 is set to the lower position – "0";

5) turn off the oscilloscope;

6) the actuator Q1 is set to the lower position – "0";

7) disconnect X2, X3 from the socket on a stationary laboratory stand (power supply to the laboratory stand and oscilloscope);

8) disconnect X1 from the socket on a stationary laboratory table (laboratory autotransformer T1).

Test questions

1. Purpose of modular circuit breakers.

2. The principle of operation of modular circuit breakers.

3. The main elements of modular circuit breakers.

4. How to install modular circuit breakers. What is a DIN rail?

5. Characteristic dimensions of modular circuit breakers.

6. What is overcurrent?

7. What types overcurrent releases do you know?

8. Time-current characteristic of the modular circuit breaker. Currents of operation and non-operation.

9. Types of time-current characteristics of modular circuit breakers.

10. Purpose and principle of operation of the free-trip mechanism.

11. Which release provides protection in the area of current overloads?

12. Which release provides protection in the area of short circuits?

13. Current-limiting ability of the modular circuit breaker.

14 What is ultimate short-circuit breaking capacity and service short-circuit breaking capacity?

15. How does the overcurrent releases affect the free-trip mechanism of modular circuit breakers?

16. What additional equipment is used to expand the functionality of modular circuit breakers?

Laboratory work 2

RESEARCH OF THE ELECTROMAGNETIC RELAYS

The purpose: to get acquainted with the design and technical characteristics of the electromagnetic relay; Testing of the functionality of devices; Determination of the minimum residual operating current.

The subject of research: electromagnetic relay Schrack PT570060 and Relpol RM84-2012-35-1060.

Task

1. Get acquainted with the purpose, principle of operation, design and technical characteristics of electromagnetic relay, as well as with electrical circuit and devices installed on the laboratory stand.

2. Research of the relay characteristics

3. Determination of operating time of electromagnetic relay.

4. Determination of contact bounce time of electromagnetic relay.

General information

Relay is an automatic electrical switch, when given a certain input signal, such as electricity, magnetism, light, heat or pressure etc and maintain a long enough time, it can automatically switch the control circuit to produce a jump change. When the input is reduced to a certain extent and maintain a long enough time, it then restored to its original state, the control circuit is also stepped back to the original status. Regardless of the relay function principle and structure of any form, it is always consisting of input circuit, comparative structure and output circuit. Therefore, the relay is a four-terminal component, and its input and output must be isolated.

Electrical relay – device designed to produce sudden and predetermined changes in one or more output circuits when certain conditions are fulfilled in the electric input circuits controlling the device.

Electromagnetic relay – electromechanical relay in which the intended response is produced by means of electromagnetic forces.

Electromechanical relay – electrical relay in which the intended response results mainly from the movement of mechanical elements.

Monostable relay – electrical relay which, having responded to an energizing quantity and having changed its condition, returns to its previous condition when that quantity is removed.

Bistable relay – electrical relay which, having responded to an energizing quantity and having changed its condition, remains in that condition after the quantity has been removed; a further appropriate energization is required to make it change its condition.

Polarized relay – elementary relay, the change of condition of which depends upon the polarity of its DC energizing quantity.

Latching Relay. A double stabilized relay remaining energizing state after energizing is gone. It is called a mechanic latching relay if the energizing state is latched mechanically. It is called a magnet latching relay if the energizing state is latched by the magnetic force from the hard magnet or half-hard magnet material.

Relays can work either as switches (turning things on and off) or as amplifiers (converting small currents into larger ones).

Rated value – value of a quantity used for specification purposes, established for a specific set of operating conditions.

Coil rated voltage – the coil voltage which make the relay work, meeting all the electrical, mechanical and environmental requirements.

Operate voltage (also named pick-up value) – value of the input voltage at which a relay operates.

Non-operate voltage (also named non-pick-up value) – value of the input voltage at which a monostable relay does not operate.

Operate time – time interval between the application of the specified input voltage to a relay in the release condition and the change of state of the last output circuit, bounce time not included.

Bounce time – for a contact, which is closing/opening its circuit, time interval between the instant when the contact circuit first closes/opens and the instant when the circuit is finally closed/opened.

Schrack *PT570060* (Fig. 1):

Four-pole; Rated voltage 60V DC; Four change-over contact; Contact material: argentum-nickel AgNi 90/10; Contact rating 250V AC, 6A; Coil resistance 4845 Ω; Electrical resource 100x103 cycles; Switching power 1500 VA.

.

Fig. 1 – Electromagnetic relay Schrack PT570060

Relpol *RM84-2012-35-1060* (Fig. 2):

Rated voltage 60V DC; Rated switching voltage 250V AC; Rated current 8A; Max. breaking capacity 2000 VA; 2 change-over contact; Rated power consumption 0,48W; Mechanical resource $3x10^7$ cycles; Electrical resource 100×10^3 cycles; Coil resistance 7500 Ω; Contact material: argentum-nickel.

Fig. 2 – Electromagnetic relay Relpol RM84-2012-35-1060

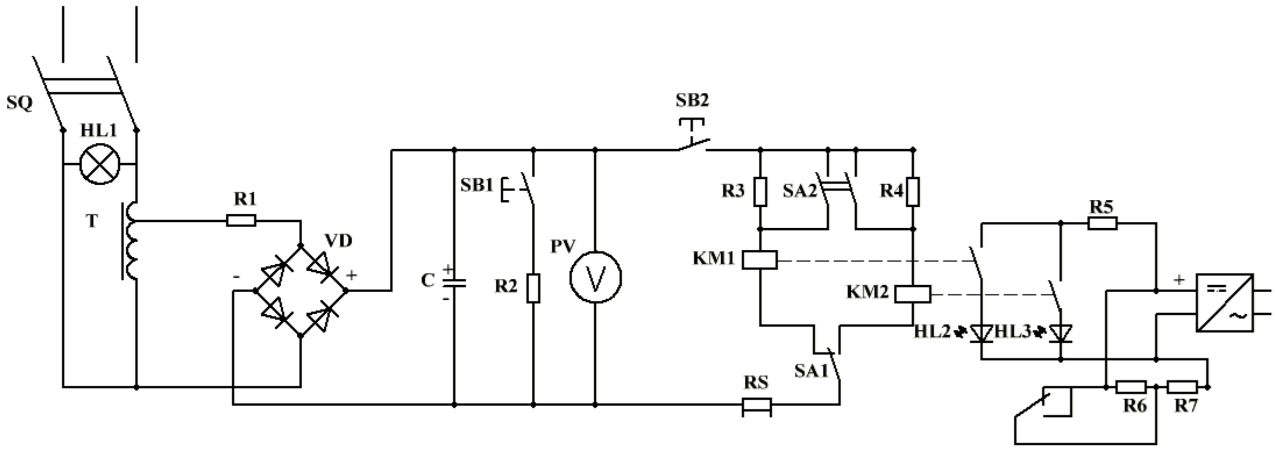

Fig. 3 – The electrical circuit research of electromagnetic relays

T	autotransformer;
HL1	signal lamp of connection of the stand to a power supply;
HL2, HL3	signal lamps of operation of the relay
VD	diode bridge;
SQ	switch in the AC circuit at the input of the laboratory stand;
C	capacitor with a capacity of 220 μF;
PV	voltmeter that monitors the supply voltage of the winding (the voltage across the capacitor C);
SB1	push-button switch in the capacitor discharge circuit C;
SB2	push-button switch in the relay coil winding circuit;
SA1	switch for relay selection;
SA2	two-pole switch in the connection circuit of the relay coil winding
RS	100 Ω resistor, oscilloscope connection shunt;
R1	130 Ω charging resistor;
R2	10 kΩ resistor, used to discharge the capacitor C;
R3	resistor 13 kΩ;
R4	resistor 22 kΩ;
R5	resistor 85 Ω;
R6	resistor 510 Ω;
R7	resistor 5,5 kΩ.

When the input circuit-breaker SQ is closed, the signal lamp HL1 lights up and the AC voltage is fed to the diode bridge VD through the laboratory autotransformer T. After converting the AC voltage to pulsating, the voltage flows through the capacitor C and goes to the voltmeter PV.

In order to discharge the capacitor C, a push-button switch SB2 and a resistor R2 are used, which are installed parallel to the capacitor.

Sequence of laboratory work

Before starting the experiments, you need to perform the operations in the following sequence:

1) Connect a voltmeter,

2) Connect the mobile laboratory stand to the sockets.

3) Connect the stand to the laboratory autotransformer T.

4) Connect the oscilloscope to the socket.

5) the actuator SQ is set in the upper position - "I";

Experiment 1

Research of the relay characteristics

Determine the operating and release voltages of the relays Schrack PT570060 and Relpol RM84-2012-35-1060.

The relay characteristic shows at what range of voltages the relay works and releases.

The relay characteristic Schrack PT570060 at a rated voltage of the control circuit 60V DC is shown in the Fig. 4. The operating and release voltage of the relay Schrack PT570060 is 35V and 13V, respectively.

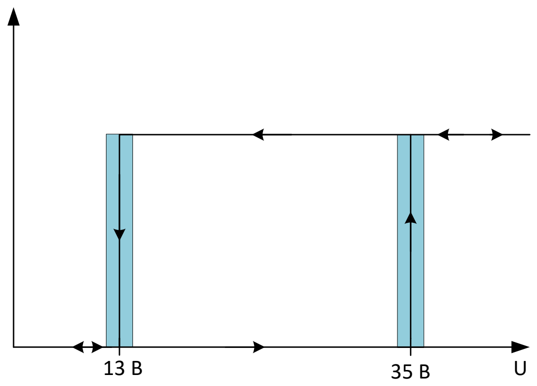

Fig. 4 – The relay characteristic Schrack PT570060

The relay characteristic Relpol RM84-2012-35-1060 at a rated voltage of the control circuit 60V DC is shown in the Fig. 5.

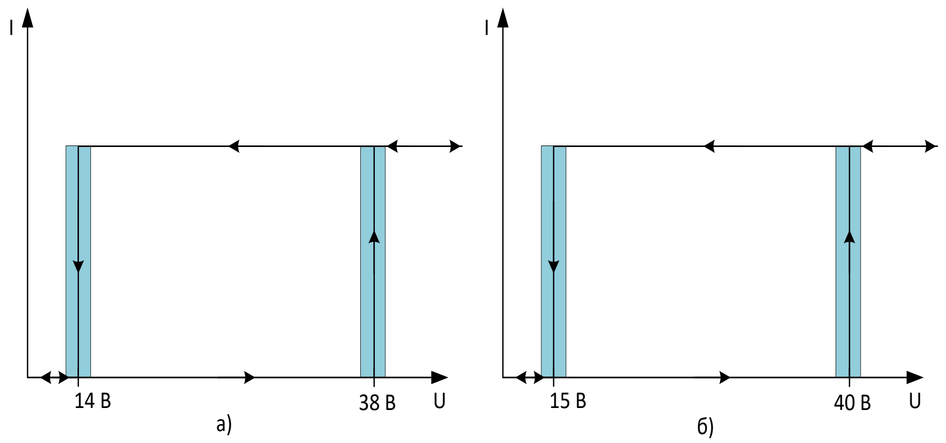

Fig. 5 – The relay characteristics Relpol RM84-2012-35-1060

As shown in Fig. 5, several relays from the same batch may have different relay characteristics and the manufacturer usually specifies the ranges of operation/release of the relay in which they should be included.

Determine the operating and release voltages of the relay Schrack PT570060 should be performed in the following sequence:

1) for research of the Schrack relay at voltage of 60V the switches SA1 and SA2 are set to the lower position;

2) slowly rotating the handle of the autotransformer T to fix the voltage of

operation and release of the relay;

3) for research the relay at 220V, move the switch SA2 to the upper position.

Determine the operating and release voltages of the relay Relpol should be performed in the following sequence:

1) for research of the Relpol relay at voltage of 60V the switch SA1 is set to the upper position;

2) the switch SA2 is set to the lower position;

3) slowly rotating the handle of the autotransformer T to fix the voltage of operation and release of the relay;

3) for research the relay at 220V, move the switch SA2 to the upper position.

Experiment 2

Determining the operation time of interface relay Schrack PT570060

1) the actuators of switches Q1 and Q2 are set to the upper position

2) the actuators of switches SA1 and SA2 are set to the lower position

3) Connect one of the oscilloscope probes to a voltage divider RS

4) Connect other of the oscilloscope probes to a voltage divider R3

5) Using a laboratory autotransformer T to set the supply voltage of the mobile laboratory stand to 60 V

6) Use the SA2 button to get oscillograms

7) Use the oscilloscope to record the voltage and current characteristics at the time of closing operation.

8) the actuator of switch SA2 is set to the upper position

9) using a laboratory autotransformer T to set the supply voltage of the mobile laboratory stand to 220 V

10) use the SA2 button to get oscillograms

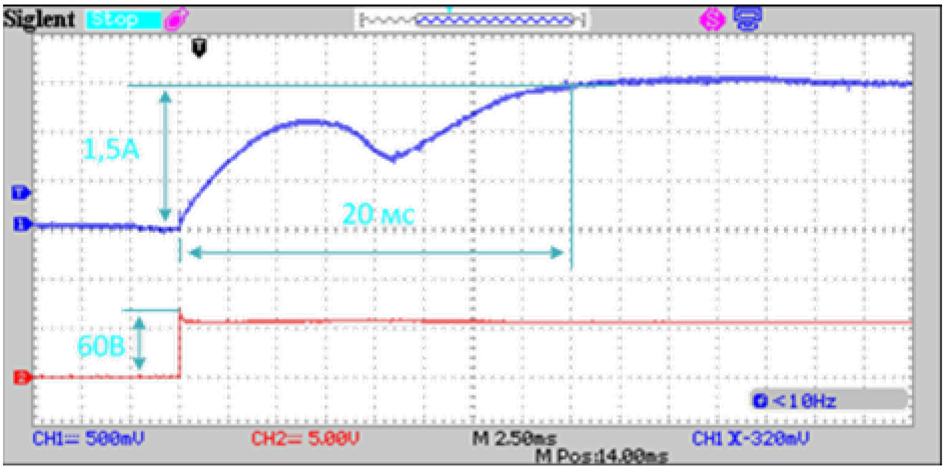

Fig. 6 – Oscillogram of relay operation Schrack PT570060

11) use the oscilloscope to record the voltage and current characteristics at the time of closing operation.

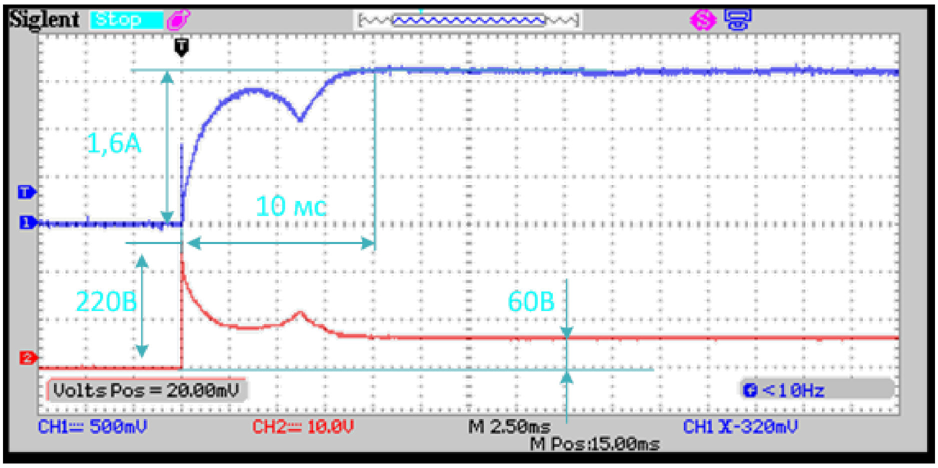

Fig. 7 – Oscillogram of relay operation Schrack PT570060 at 220 V

Using oscillograms to determine the operate time of the contacts of the relay.

The oscillograms obtained during the experiments allow to accurately determine and set the time and voltage of the relay.

From the oscillogram (Fig. 6) it is seen that when applied to the coil rated voltage 60V: the current on the coil - 1.5 A, the total operating time of 20 msec.

From the oscillogram (Fig. 7) it is seen that when applied to the coil rated voltage 220V: the current on the coil - 1.6 A, the total operating time of 10 msec. At the first moment of time the voltage on the coil is 220V and at final operation decreases to 60V

Experiment 3

Determining the operation time of the relay Relpol RM84-2012-35-1060

1) the actuators of switches Q1 and SQ are set to the upper position

2) the actuator of switch SA1 is set to the upper position

3) the actuator of switch SA2 is set to the lower position

4) connect one of the oscilloscope probes to a voltage divider RS

5) connect other of the oscilloscope probes to a voltage divider R4

6) using a laboratory autotransformer T to set the supply voltage of the mobile laboratory stand to 60 V

7) use the SA2 button to get oscillograms

8) use the oscilloscope to record the voltage and current characteristics at the time of closing operation.

9) the actuator of switch SA2 is set to the upper position

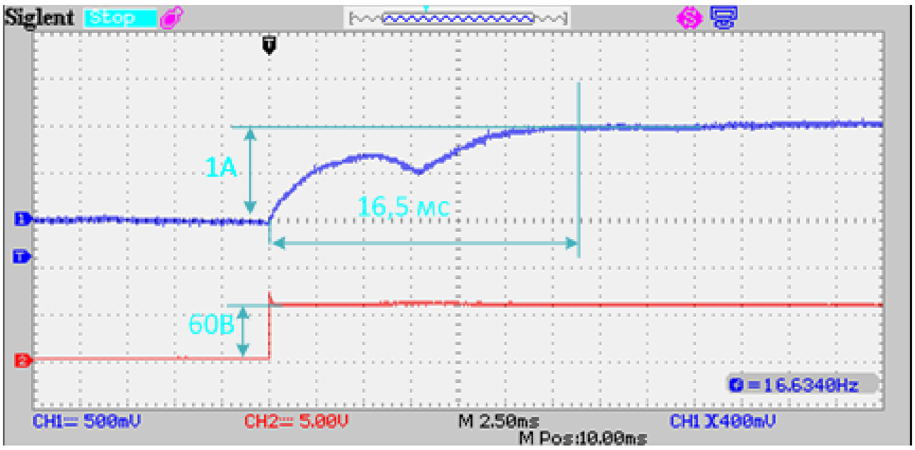

Fig. 6 – Oscillogram of relay operation Relpol RM84-2012-35-1060

10) using a laboratory autotransformer T to set the supply voltage of the mobile laboratory stand to 220 V

11) use the SA2 button to get oscillograms

12) use the oscilloscope to record the voltage and current characteristics at the time of closing operation.

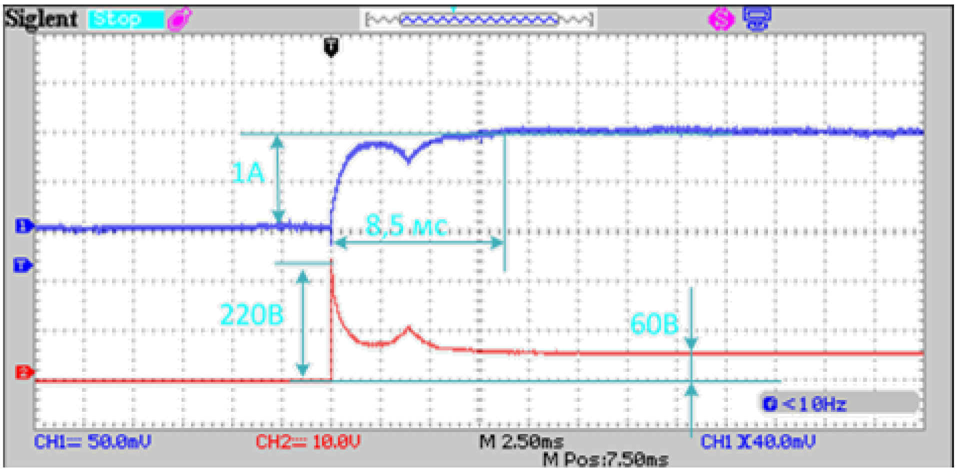

Fig. 7 – Oscillogram of relay operation Relpol RM84-2012-35-1060 at 220 V

Using oscillograms to determine the closing time of the contacts of the relay.

The oscillograms obtained during the experiments allow to accurately determine and set the time and voltage of the relay.

From the oscillogram (Fig. 6) it is seen that when applied to the coil rated voltage 60V: the current on the coil - 1 A, the total operating time of 16.5 msec.

From the oscillogram (Fig. 7) it is seen that when applied to the coil rated voltage 220V: the current on the coil - 1 A, the total operating time of 8.5 msec. At the first moment of time the voltage on the coil is 220V and at final operation decreases to 60V.

Experiment 4

Determining the contacts vibration time of the relay Relpol. The contacts vibration is caused by the fact that spring contacts at collision are inclined to transfer to each other kinetic energy, thus there are vibrations and short-term disturbances of electric contact.

Research of contacts vibration relay Relpol RM84-2012-35-1060 during the closing operation should be performed in the following sequence:

1) the actuators of switches Q1 and SQ are set to the upper position

2) the actuator of switch SA1 is set to the upper position

3) the actuator of switch SA2 is set to the lower position

4) connect one of the oscilloscope probes to a voltage divider RS

5) connect the second of the oscilloscope probes to a voltage divider consisting of resistors R6 and R7

6) using a laboratory autotransformer T to set the supply voltage of the mobile laboratory stand to 60 V

7) use the SA2 button to get oscillograms

8) use the oscilloscope to record the voltage and current characteristics at the time of closing operation.

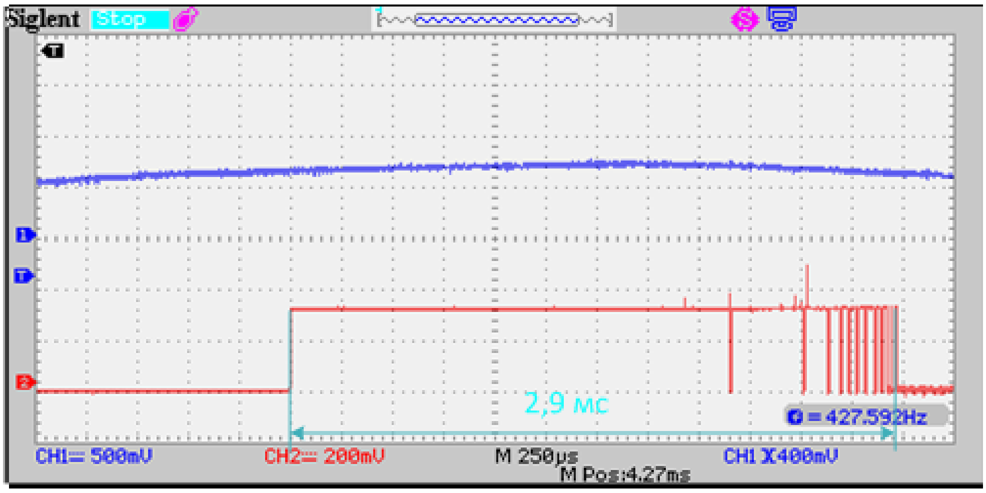

Fig. 8 – Oscillogram of contacts vibration Relpol RM84-2012-35-1060 at 60 V

9) the actuator of switch SA2 are set to the upper position

10) using a laboratory autotransformer T to set the supply voltage of the mobile laboratory stand to 220 V

11) use the SA2 button to get oscillograms

12) use the oscilloscope to record the voltage and current characteristics at the time of closing operation.

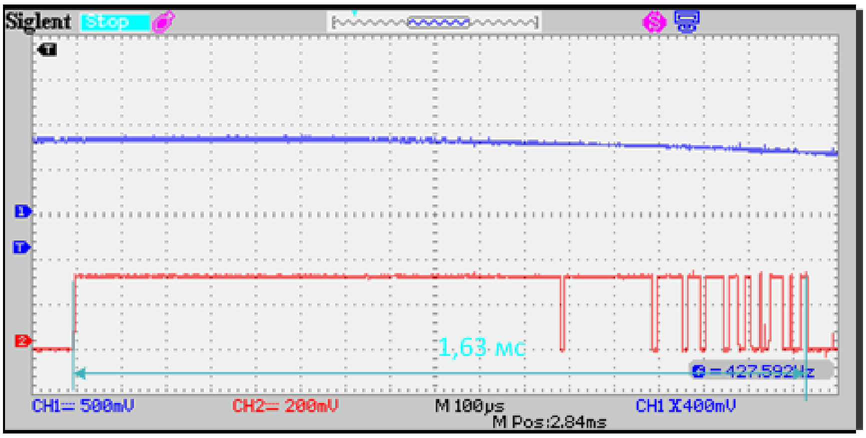

Fig. 9 – Oscillogram of contacts vibration Relpol RM84-2012-35-1060 at 220 V

All data and oscillograms obtained during laboratory work must be included in the report.

Test questions

1. Purpose of electromagnetic relays.
2. The principle of operation and design of electromagnetic relays.
3. Basic requirements for electromagnetic relays.
4. What are neutral and polarized relays?
5. What is a relay characteristic?
6. What is the parameter of operation and opening of the relay?
7. What is the return coefficient of the relay?
8. How does the operating time depend on the voltage applied to the relay electromagnet winding?
9. From what materials are the contacts of electromagnetic relays made? Why are precious metals used for electromagnetic relay contacts?
10. How is the installation of electromagnetic relays?

Laboratory work 3

RESEARCH OF VACUUM CONTACTOR WITH FORCED ELECTROMAGNETIC ACTUATING SYSTEM

The purpose: acquaintance with a construction and technical characteristics of the vacuum contactor, 250 A, 1140 V; check of serviceability of the contactor; research of contacts vibration.

The subject of research: a vacuum contactor, 250A, 1140 V.

This laboratory work researches three-pole vacuum contactor series KVTn-250 / 1,14-0 of the "Electrodynamics" factory. Vacuum contactors of KVTn type are used in systems for remote control of electric drives on mine equipment

Task:

1. Learn the purpose, principle of operation, design and technical characteristics of the vacuum contactor; research the electrical circuit of the laboratory work, the purpose of the devices and apparatus installed on the laboratory stand.
2. Determine the closing voltage and opening voltage.
3. Determine the voltage and current in the boosting coil and in the holding coil during the closing operation.
4. Research of contacts vibration during the closing operation

General information

Contactor (mechanical) – mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions.

The term "operated otherwise than by hand" means that the device is intended to be controlled and kept in working position from one or more external supplies. AC and DC contactors intend for closing and opening electric circuits. A contactor is usually intended to operate frequently.

Electromagnetic contactor – contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by an electromagnet.

Vacuum contactor – contactor in which the main contacts open and close within a highly evacuated envelope.

Position of rest (of a contactor) – position which the moving elements of the contactor take up when its electromagnet or its compressed-air device is not energized [IEV 441-16-24].

Rated operational voltage (U_e). A rated operational voltage of an equipment is a value of voltage which, combined with a rated operational current, determines the application of the equipment and to which the relevant tests and the utilization categories are referred. For single-pole equipment, the rated operational voltage is generally stated as the voltage across the pole. For multipole equipment, it is generally stated as the voltage between phases.

Rated operational currents (I_e). A rated operational current of a contactor is stated by the manufacturer and takes into account the rated operational voltage, the conventional free air or enclosed thermal current, the rated current of the overload relay, the rated frequency, the rated duty, the utilization category and the type of protective enclosure, if any.

Protective conductor (symbol PE) – conductor required by some measures for protection against electric shock for electrically connecting any of the following parts:

– exposed conductive parts;

– extraneous conductive parts;

– main earthing terminal;

– earth electrode;

– earthed point of the source or artificial neutral.

Neutral conductor (symbol N) – conductor connected to the neutral point of a system and capable of contributing to the transmission of electrical energy.

Live part – conductor or conductive part intended to be energized in normal use, including a neutral conductor but, by convention, not a PEN conductor.

Contact (of a mechanical switching device) – conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

Release (of a mechanical switching device) – device, mechanically connected to a mechanical switching device, which releases the holding means and permits the opening or the closing of the switching device

Actuating system (of a mechanical switching device) – whole of the operating means of a mechanical switching device which transmit the actuating force to the contact pieces.

Actuator – part of the actuating system to which an external actuating force is applied.

Ability to withstand motor switching overload currents. An equipment intended for switching motors, like a contactor, shall be capable of withstanding the thermal stresses due to starting and accelerating a motor to normal speed and due to operating overloads.

Before starting work, it is necessary to carefully learn the electrical circuit research of vacuum contactors (Fig. 1), the purpose of devices and apparatus installed on the laboratory stand with the help of these guidelines.

Switch Q1 connects the AC power supply to the power supply circuit of a stationary laboratory table. The HL1 light signals the presence of power to a stationary laboratory table. The mobile laboratory stand is connected to the X3 socket by means of an electric plug. Switch Q2 connects the AC power source to the power supply circuit of the mobile laboratory stand. The HL2 light signals the presence of the power supply of the mobile laboratory stand circuit.

The voltage divider consists of four resistors R1, R2, R3 and R4, which have a resistance of 56 kΩ, 510 kΩ, 56 kΩ, 510 kΩ, respectively. The laboratory autotransformer T1, which is connected to the connector X1 with an electric plug, regulates the voltage U. The voltage is controlled by a voltmeter PV. Switch Q3 connects the AC power source to the control circuit of the vacuum contactor. The oscilloscope is connected to the X2 socket with an electric plug. Two resistors R5 and R6 are connected to research of contacts vibration during the closing operation.

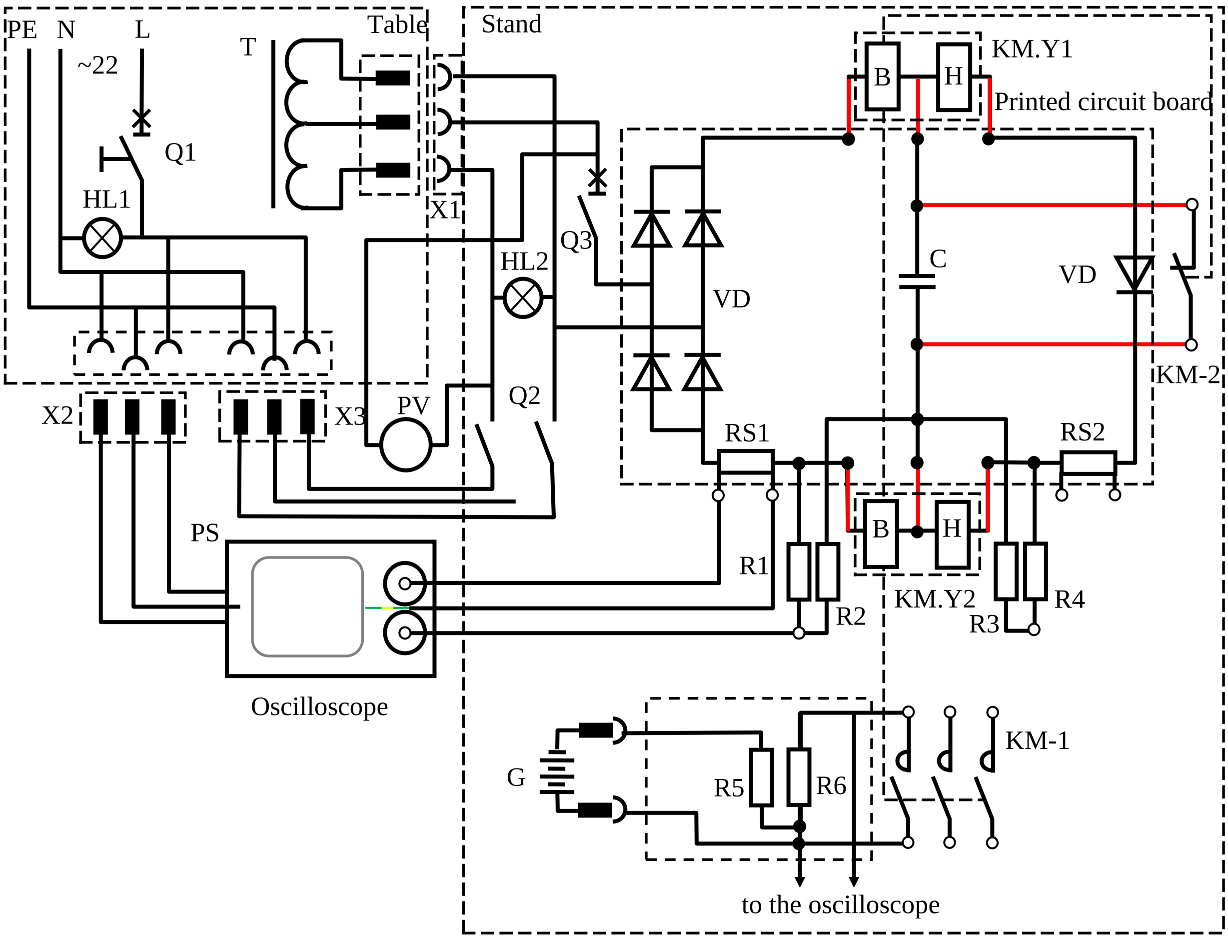

Fig. 1 – The electrical circuit research of the vacuum contactor

Electromechanical forced control system (Fig. 2) is used in low and medium voltage vacuum contactors. It contains a diode bridge (VD1), two coils (Y1, Y2) with two windings: booster (B) and holding (H), diode (VD2), capacitor (C) and normally closed block contact (S1) located in the auxiliary contact block of the contactor. The electromagnet contains two coils, each of which consists of a booster and holding windings. Both windings are located in one coil and are wound on top of each other.

The booster winding contains a small number of turns. It is wound with a wire of large enough cross-section and develops a significant magnetomotive force. The booster winding cannot be connected to the power supply for a long time due to the release of a large amount of energy in it.

The holding winding is wound with a wire of small cross section, contains a large number of turns. This winding releases a small amount of energy, so it can work for a long time. The magnetomotive force of the holding winding is much smaller than the boosting, but this magnetomotive force is sufficient to keep the armature of electromagnet in the closed position.

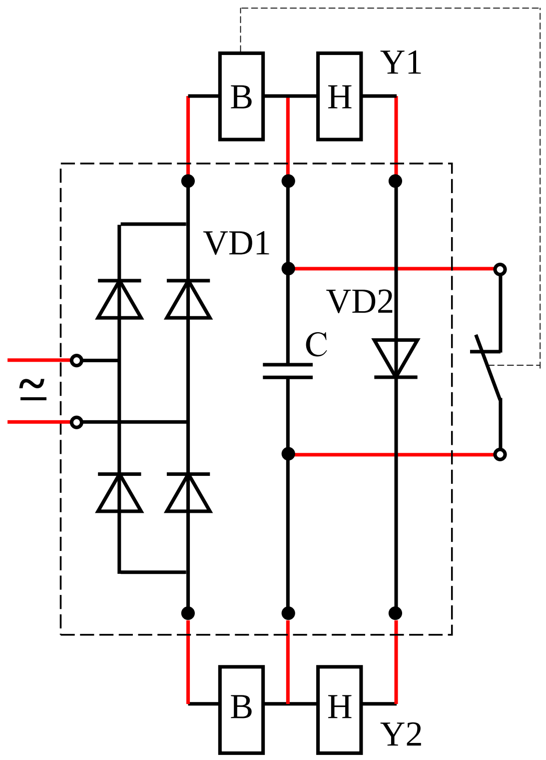

Fig. 2 – Electromechanical forced control system of contactor

Beginning of the closing operation of contactor (Fig. 3). An alternating voltage of 220 V is supplied to the input of the diode bridge, and a rectified voltage is applied to the coil of the electromagnet. The rectified current flows through the boosting winding and the block contact (red lines - current path), which leads to the actuation of the electromagnetic drive, which mechanically acts on the block contact, that is, opens it.

End of the closing operation of contactor (Fig. 4). The auxiliary contact opens only after the magnetic system is closed. Premature opening of the auxiliary contact interferes with the closing operation of the electromagnet, due to the fact that the magnetic flux does not have time to take the value required to close the magnetic system. During the opening operation the vibration of auxiliary contact is possible, that is, repeated closure and opening of auxiliary contact, which can lead to vibration of the magnetic system, which directly affects the moving contacts in the vacuum interrupters. To avoid vibration, the block-contact is shunted with a capacitor (dotted line, Fig. 4)

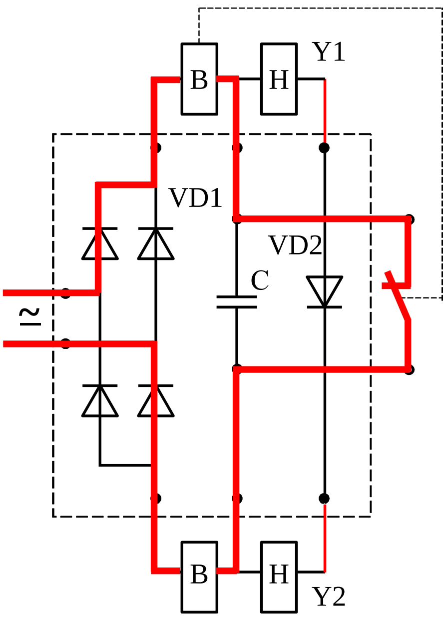

Fig. 3 – Beginning of the closing operation

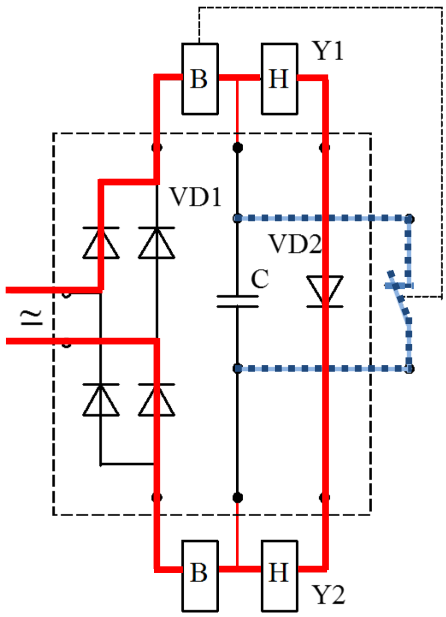

Fig. 4 – End of the closing operation

After opening the block-contact, the current begins to flow through the holding winding through the VD2 diode. The VD2 diode in the electrical circuit allows to avoid a short circuit, there is no counter current and the closing process is not inhibited. The resistance of the holding winding is high enough and thus the holding current is negligible compared to the starting current.

Sequence of laboratory work

Before starting the experiments, you need to perform the operations in the following sequence:

1) Connect the mobile laboratory stand to the X3 socket.

2) Connect the stand to the laboratory autotransformer T using connector X1.

3) Connect the oscilloscope to the X2 socket.

The oscilloscope terminals connect to resistors RS1 and RS2 with resistances of 0,1 Ohm and 10 Ohm, respectively.

Experiment 1

Determine the closing voltage and opening voltage should be performed in the following sequence:

1) Switch on switches Q1, Q2 and Q3.

2) Using a laboratory autotransformer T to raise the supply voltage of the mobile laboratory stand until the contacts of the vacuum contactor are closed. Write the data from the PV voltmeter in Table 1.

3) Using a laboratory autotransformer T to reduce the supply voltage of the mobile laboratory stand until the opening of the contacts of the vacuum contactor. Write the data from the PV voltmeter in Table 1.

Table 1 – Determine the closing voltage and opening voltage

U, V	The experiment №				
	1	2	3	4	5
U_I					
U_O					

The Table 1 must be included in the report.

Experiment 2

Determine the voltage and current in the boosting coil and in the holding coil during the closing operation should be performed in the following sequence:

1) the actuators of switches Q1 and Q2 are set to the upper position

2) Using a laboratory autotransformer T to set the supply voltage of the mobile laboratory stand to 150 V

3) the Q3 actuator is set to the upper position

4) Use the oscilloscope to record the voltage and current characteristics of boosting and holding coils at the time of closing operation.

5) Repeat the study 2 more times, increasing the voltage to 180 V and 220 V.

The oscillograms of current and voltage of boosting and holding coils at the time of closing operation at voltages of 150 V, 180 V and 220 V must be included in the report.

Using oscillograms to determine the closing time of the contacts of the vacuum contactor at all voltage values.

Experiment 3

Research of contacts vibration during the closing operation should be performed in the following sequence:

1) Connect one of the oscilloscope probes to a voltage divider consisting of resistors R5 and R6

2) Connect the second of the oscilloscope probes to a voltage divider RS1 to obtain an oscillogram of the boosting coil current

3) Connect the crown battery

4) The actuators of switches Q1 and Q2 are set to the upper position

5) Using a laboratory autotransformer T to set the supply voltage of the mobile laboratory stand to 150 V

6) The Q3 actuator is set to the upper position

7) The oscillogram obtained from the voltage divider R5R6 shows the vibration of the moving contact and allows to calculate the vibration time and the number of rebounds.

8) Determine the closing time (t) of the vacuum contactor, the number of contact rebounds and the vibration time (Δt)

9) Experiments are performed for each of the three poles (P1, P2, 33) of the vacuum contactor at three voltage values 150 V, 180 V and 220 V

10) The results of the experiments are listed in Table 2

Table 2 – Research of contacts vibration

Poles	*U*, V	*t*, ms	Number of rebounds	Δ*t*, ms
P_1	150			
	180			
	220			
P_2	150			
	180			
	220			
P_3	150			
	180			
	220			

Table 2 and the oscillograms obtained during the experiment 3 must be included in the report.

Test questions

1. Purpose of vacuum contactors.
2. The principle of operation of the vacuum contactor.
3. The construction elements of the contactor.
4. Utilization categories of contactors.
5. Operating modes of contactors.
6. Electrical and mechanical durability of the contactor.
7. What determines the closing time and opening time of the contactor?
8. Arc extinguishing systems of contactors.
9. What is under-voltage relay?
10. Ability to withstand motor switching overload currents.

Laboratory work 4

RESEARCH OF THE RESIDUAL CURRENT OPERATED CIRCUIT-BREAKERS

The purposes: to get acquainted with the design and technical characteristics of Residual Current operated Circuit-Breakers without integral overcurrent protection (RCCBs, IEC 61008-1) and Residual current operated Circuit-Breakers with integral Overcurrent protection (RCBOs, IEC 61009-1) for household and similar uses; Testing of the functionality of devices; Determination of the minimum residual operating current.

The subject of research: RCCB functionally independent of line voltage; RCBO functionally dependent on line voltage.

Task

1. Get acquainted with the purpose, principle of operation, design and technical characteristics of RCCB and RCBO, as well as with electrical circuit and devices installed on the laboratory stand.

2. Test the functionality of devices and determine the minimum value of the mains voltage at which this test is possible.

3. Determine the residual operating current of RCCB functionally independent of line voltage and RCBO functionally dependent on line voltage.

4. Research the dependence of the operation time of RCCB and RCBO on the value of the residual current.

General information

Residual Current operated Circuit-Breaker (RCCB) – a mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions.

These devices are intended to protect persons against indirect contact, the exposed conductive parts of the installation being connected to an appropriate earth electrode. They may be used to provide protection against fire hazards due to a persistent earth fault current, without the operation of the overcurrent protective device. RCBOs functionally dependent on line voltage.

RCCBs can be functionally independent of, or functionally dependent on, line voltage, for household and similar uses, not incorporating overcurrent protection, for rated voltages not exceeding 440 V AC. and rated currents not exceeding 125 A, intended principally for protection against shock-hazard.

Residual current operated Circuit-Breakers with integral Overcurrent protection (RCBOs) – RCBOs combine residual current and miniature circuit-breakers in a single device. They protect people against residual currents and systems against short-circuit and overload.

RCBOs functionally independent of line voltage – RCBOs for which the functions of detection, evaluation and interruption do not depend on the line voltage.

RCBOs functionally dependent on line voltage – RCBOs for which the functions of detection, evaluation or interruption depend on the line voltage.

Main circuit (of a RCBO or RCCB) – all the conductive parts of devices included in the current paths.

Standard values of rated residual operating current ($I_{\Delta n}$) are:

0,006 – 0,01 – 0,03 – 0,1 – 0,3 – 0,5 A.

Standard value of residual non-operating current ($I_{\Delta no}$) is $0{,}5I_{\Delta n}$

Overcurrent – any current exceeding the rated current.

Overload current – an overcurrent occurring in an electrically undamaged circuit. An overoad current may cause damage if sustained for a sufficient time.

Short-circuit current – an overcurrent resulting from a fault of negligible impedance between points intended to be at different potentials in normal service. A short-circuit current may result from a fault or from an incorrect connection.

Break time of a RCCB – the time which elapses between the instant when the residual operating current is suddenly attained and the instant of arc extinction in all poles.

RCCB Type AC. RCCB for which tripping is ensured for residual sinusoidal alternating currents, whether suddenly applied or slowly rising.

RCCB Type A. RCCB for which tripping is ensured for residual sinusoidal alternating currents and residual pulsating direct currents, whether suddenly applied or slowly rising.

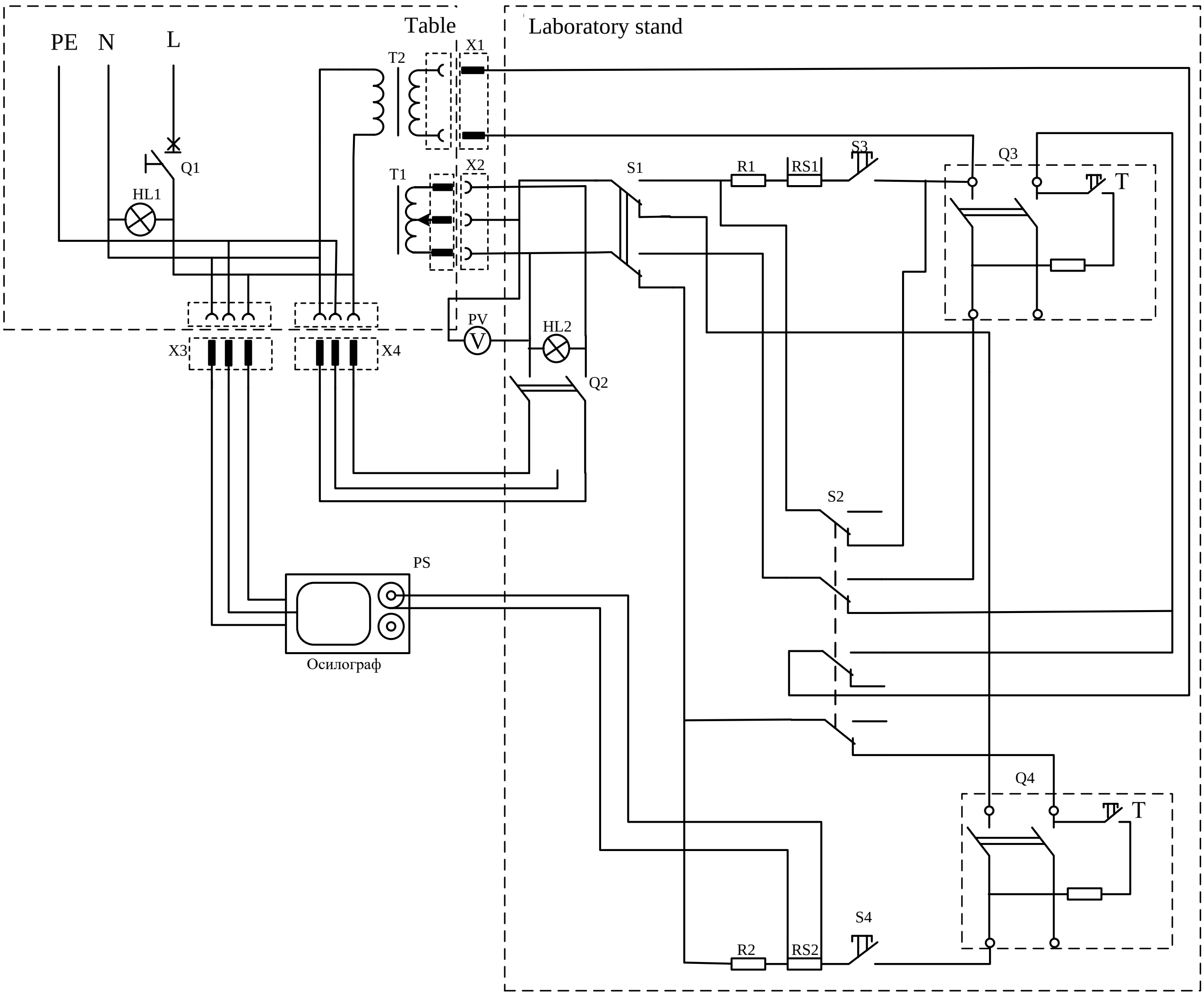

Fig. 1 – The electrical circuit research of RCCB and RCBO

Switch Q1 connects the AC power supply to the power supply circuit of the stationary laboratory table. The HL1 light signals the presence of power to a stationary laboratory table. Switch Q2 connects the AC voltage source to the power supply circuit of the mobile laboratory stand. The HL2 light indicates the presence of power to the circuit of the mobile laboratory stand. Switch S1 performs switching in the circuit for experiment Q3 (RCBO) or Q4 (RCCB). Switch S2 switches in the circuit to check the efficiency of Q3 or Q4 using the Test button, or to determine the value of the residual current of devices, and the dependence of the time of devices on the residual current.

The laboratory autotransformer T1 regulates the voltage *U*, which is controlled by a voltmeter PV (when checking the efficiency of RCD), or the current I_{Δ}, which is determined by the voltage *U* and the sum of the resistances of resistors R1 and RS1 or R2 and RS2, which is equal to 1 kΩ (when determining the residual current of devices, and the dependence of the devices operation time on the residual current). Thus, this resistance of the resistors allows you to set the leakage current using a voltmeter, one volt is equal to one milli ampere (mA). The transformer T2 (as T2 we use the transformer TC-180-2) supplies power to the amplifier RCBO Q3 and provides galvanic isolation in the circuit.

Sequence of laboratory work

Before starting the experiments, you need to perform the operations in the following sequence:

1) Connect a voltmeter,

2) Connect X1 to the corresponding socket on a stationary laboratory table (power supply of amplifier Q3),

3) Connect X2 to the appropriate socket on a stationary laboratory table (laboratory autotransformer T1),

4) Connect X3, X4 to the socket on a stationary laboratory table (power supply of the laboratory stand and oscilloscope)

5) the handle Q1 is set in the upper position - "I";

6) the handle Q2 is set in the upper position - "I";

Experiment 1

Check the operability of the RCBO (Q3) functionally dependent on line voltage (simplified scheme is shown in Fig. 2) should be performed in the following sequence:

1) the handle of the switch S1 is set in the upper position for the study Q3.

2) the actuator of the switch S2 is set to the lower position - "0"

3) the Q3 actuator is set to the upper position - "I";

4) using a laboratory autotransformer T1 set the voltage *U*, which is controlled by a voltmeter PV, in accordance with table. 1;

5) press the Test button; if the Q3 is disconnected, it means that at a given voltage, the operability checking is possible and in a certain cell of the table. 1 write "+", if the device is not turned off, write "–".

Actions according to items 3 - 5 are carried out at voltage values *U* specified in table 1.

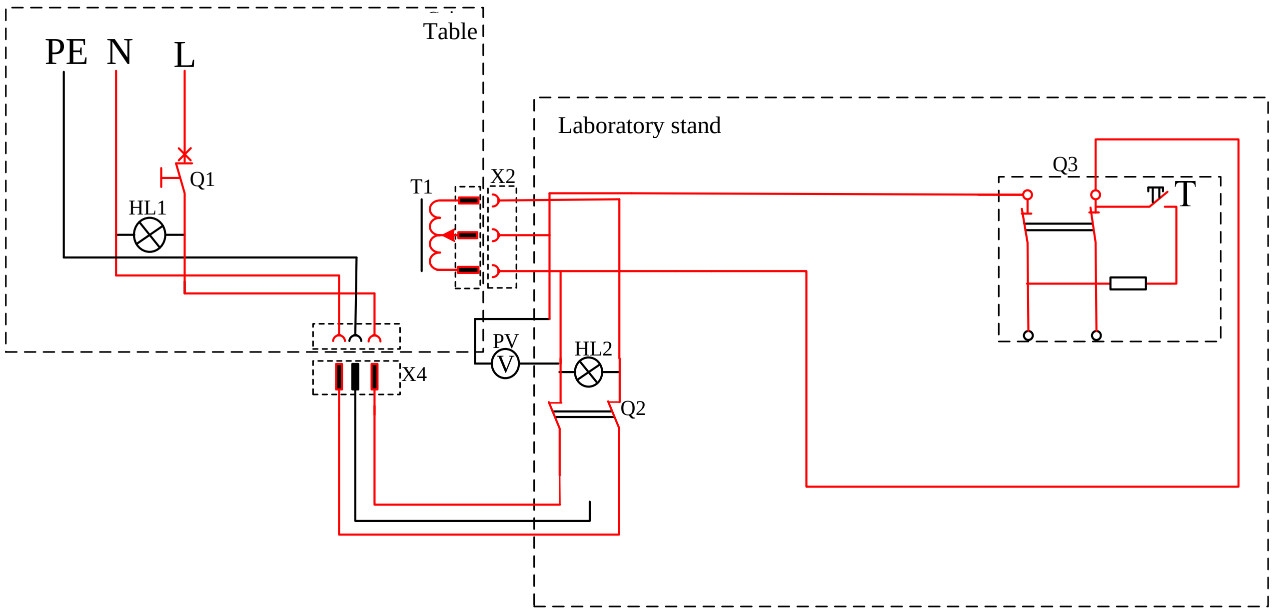

Fig. 2 – Simplified circuit for checking the operability of RCBO Q3

Table 1 – The operability checking of the RCBO Q3

U, V	45	55	65	75	120	140	160	180	200	220
The operability of Q3 during testing										

Experiment 2

Check the operability of the RCCB (Q4) functionally independent of line voltage (simplified scheme is shown in Fig. 3) should be performed in the following sequence:

1) the handle of the switch S1 is set in the lower position for the study Q4.

2) the actuator of the switch S2 is set to the lower position - "0"

3) the Q4 actuator is set to the upper position - "I";

4) using a laboratory autotransformer T1 set the voltage U, which is controlled by a voltmeter PV, in accordance with table 2;

5) press the Test button; if the Q4 is disconnected, it means that at a given voltage, the operability checking is possible and in a certain cell of the table. 1 write "+", if the device is not turned off, write "–".

Actions according to items 3 - 5 are carried out at voltage values *U* specified in table 2.

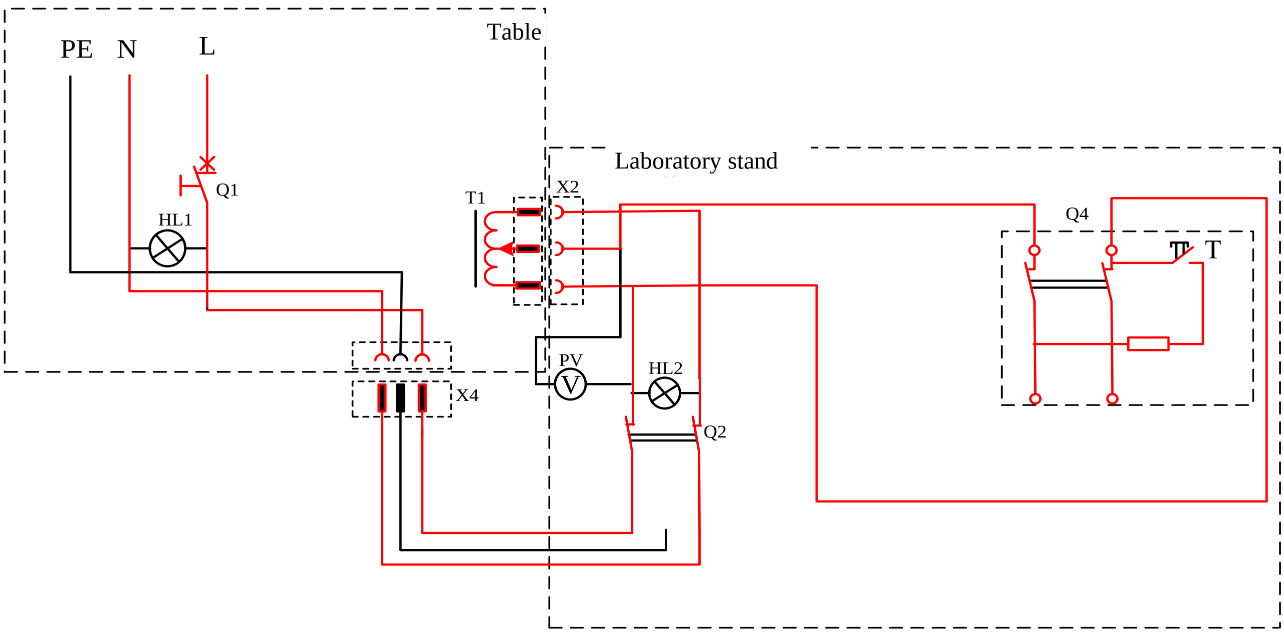

Fig. 3 – Simplified circuit for checking the operability of RCCB Q4

Table 2 – The operability checking of the RCCB Q4

U, V	45	55	65	75	120	140	160	180	200	220
The operability of Q4 during testing										

The report includes tables testing of Q3 and Q4, and the voltage *U*, in which the test performance is possible.

Experiment 3

Determine the residual operating current of Q3 $I_{\Delta n}$ should be performed in the following sequence (simplified scheme is shown in Fig. 4):

1) to study Q3 the handle of the switch S1 is set in the upper position.

2) the actuator of the switch S2 is set to the upper position - "I"

3) the Q3 actuator is set to the upper position - "I";

4) the handle of the autotransformer T1 is rotated counterclockwise until it stops;

5) press the button S3 to study Q3 and hold it;

6) the handle laboratory autotransformer T1 slowly rotated clockwise by controlling the residual current $I_{\Delta n}$ voltmeter PV (determined by the voltage *U* and the sum of the resistances of resistors R1 and RS1, which is equal to 1 kΩ), until the moment of operation.

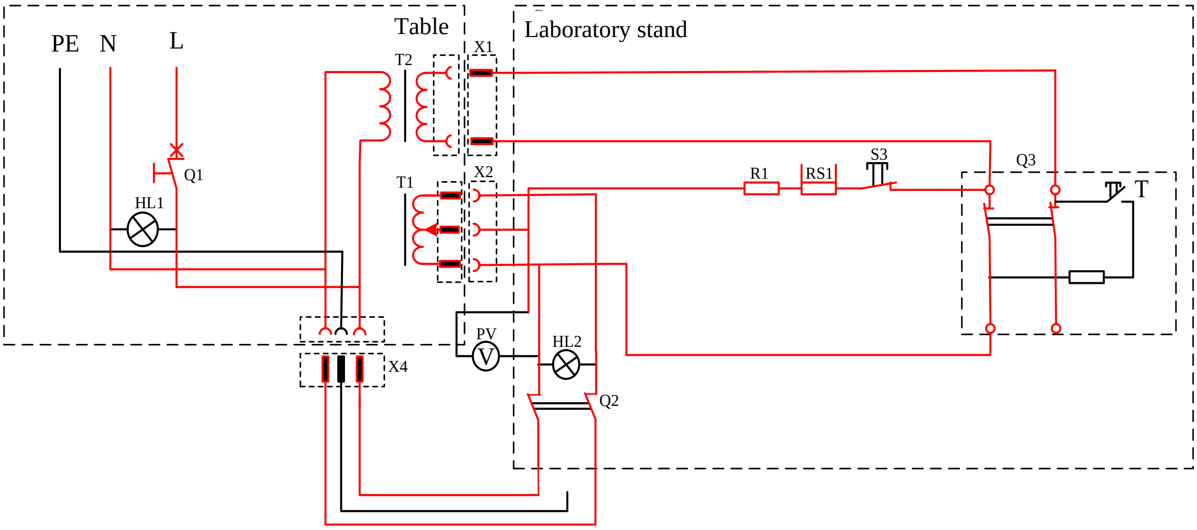

Fig. 4 – Simplified circuit for determination of the residual operating current of Q3, $I_{\Delta n}$

Actions according to items 3 - 6 are carried out 5 times, writing the value of the residual current $I_{\Delta n}$ in Table 3. According to certain data, calculate the average value.

Table 3 – Determination of the residual operating current of Q3

The experiment №	1	2	3	4	5	The average value
$I_{\Delta n}$, mA Q3						

The table of determination of the residual operating current of Q3 must be included in the report. According to the table, a conclusion is made about the compliance of Q3 (RCBO) standard IEC 755 (relative to the residual operating current).

Experiment 4

Determine the residual operating current of Q4 $I_{\Delta n}$ should be performed in the following sequence (simplified scheme is shown in Fig. 5):

1) to study Q4 the handle of the switch S1 is set in the lower position.

2) the actuator of the switch S2 is set to the upper position - "I"

3) the Q4 actuator is set to the upper position - "I";

4) the handle of the autotransformer T1 is rotated counterclockwise until it stops;

5) press the button S4 to study Q4 and hold it;

6) the handle laboratory autotransformer T1 slowly rotated clockwise by controlling the residual current $I_{\Delta n}$ voltmeter PV (determined by the voltage U and the sum of the resistances of resistors R2 and RS2, which is equal to 1 kΩ), until the moment of operation.

Actions according to items 3 - 6 are carried out 5 times, writing the value of the residual current $I_{\Delta n}$ in Table 4. According to certain data, calculate the average value.

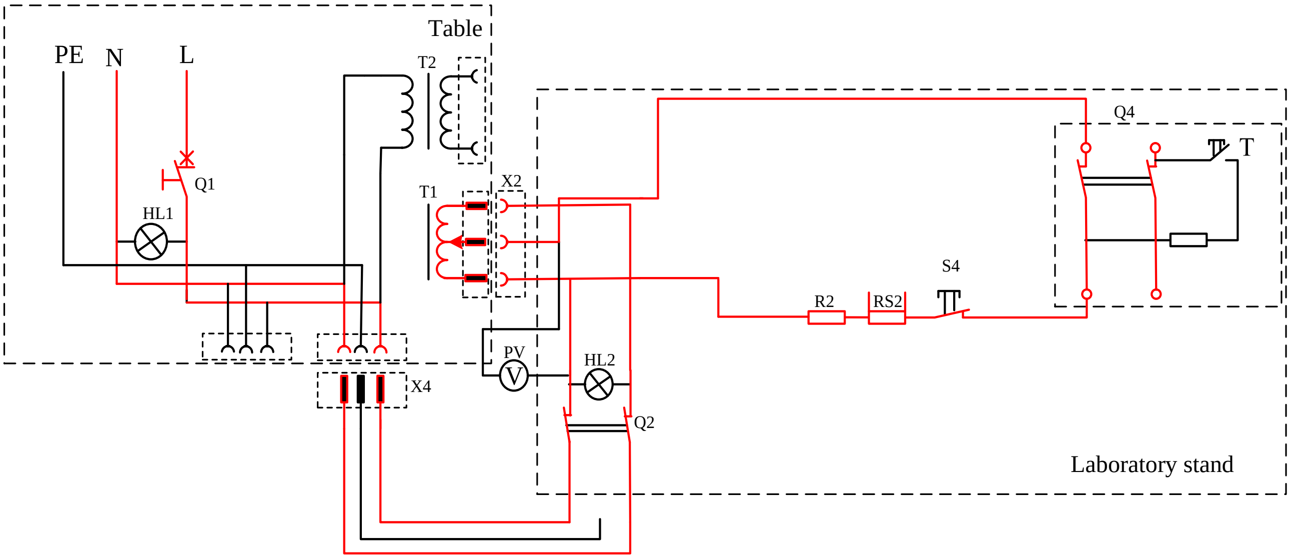

Fig. 5 – Simplified circuit for determination of the residual operating current of Q4, $I_{\Delta n}$

Table 4 – Determination of the residual operating current of Q4

The experiment №	1	2	3	4	5	The average value
$I_{\Delta n}$, mA Q4						

The table of determination of the residual operating current of Q4 must be included in the report. According to the table, a conclusion is made about the compliance of Q4 (RCCB) standard IEC 755 (relative to the residual operating current).

Experiment 5

Determination of the dependence of tripping time t_{tr} of the RCBO (Q3) functionally dependent on line voltage on the value of the residual current $I_{\Delta n}$ is carried out in the following sequence (a simplified scheme is shown in Fig. 6):

1) the handle of the autotransformer T1 is rotated counterclockwise until it stops;

2) the oscilloscope is connected to the RS1 terminals and set voltage 5V;

3) the handle of the switch S1 is set in the upper position;

4) the actuator of the switch S2 is set to the upper position - "I";

5) the handle laboratory autotransformer T1 slowly rotated clockwise to set the

residual current $I_{\Delta n}$ according to the table. 5, controlling the current with a voltmeter PV, which is determined by the voltage U and the sum of the resistances of resistors R1 and RS1 which is equal to 1 kΩ;

6) the Q3 actuator is set to the upper position - "I";

7) press the button S3;

8) according to the oscilloscope to record the tripping time t_{tr} of Q3 (Fig.7).

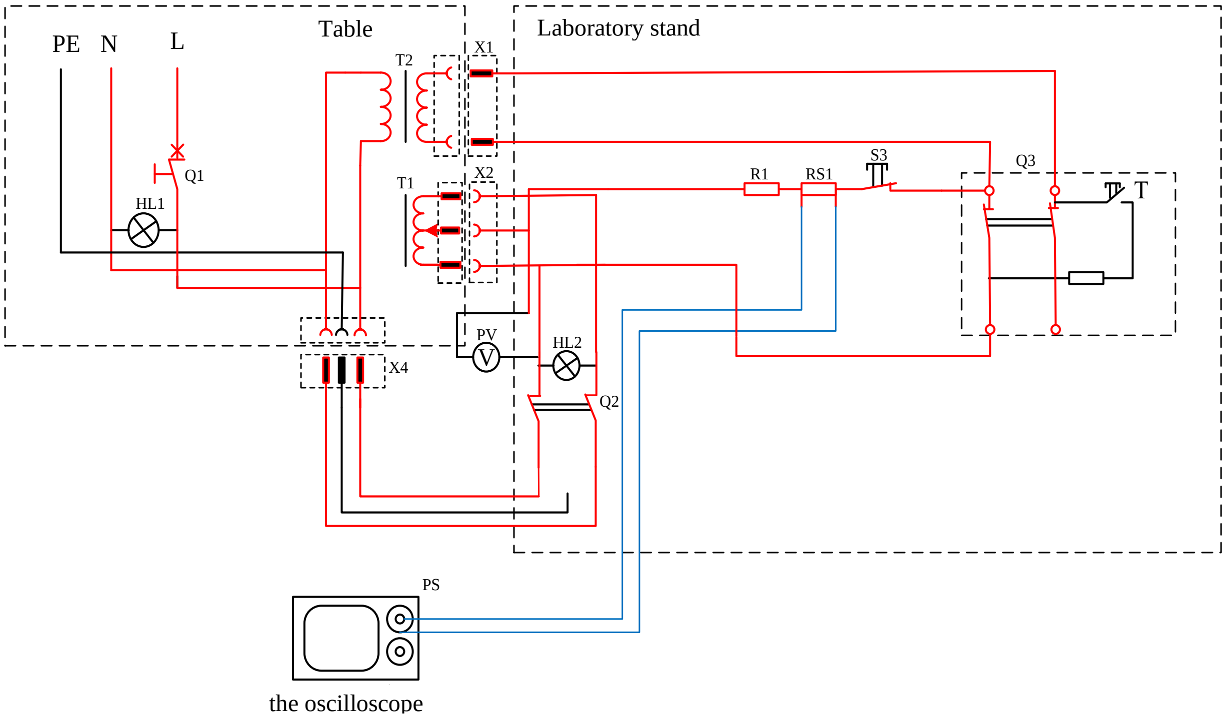

Fig. 6 – Simplified circuit for determination of the dependence of tripping time t_{tr} of the RCBO (Q3) functionally dependent on line voltage on the value of the residual current $I_{\Delta n}$

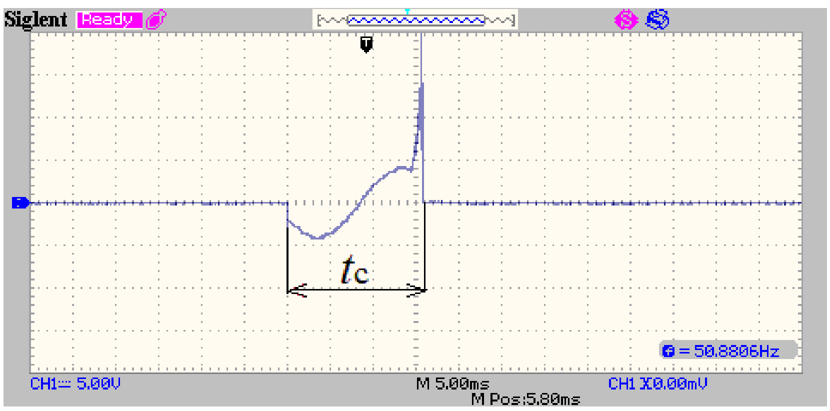

Fig. 7 – Oscillogram of current in the Q3 pole

Actions according to items 6 - 8 are carried out 10 times for each value of the residual current, writing the value of the tripping time of Q3 to table. 5. According to the determined data, calculate the average, minimum and maximum value of the tripping time. The table of determination of the dependence of tripping time t_{tr} on the value of the residual current $I_{\Delta n}$ must be included in the report. According to the table 5 build the functional dependence of the tripping time of the device (average value t_{tr}) on the value of the residual current $t_{tr} = f(I_{\Delta n})$.

Table 5 – The results of the experiment to determine the dependence of the tripping time t_{tr} of the RCBO (Q3) functionally dependent on line voltage on the value of the residual current $I_{\Delta n}$

The experiment №	The value of the residual current I_{Δ} , mA					
	22	26	30	34	38	42
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Average value						
Minimum value						
Maximum value						

Experiment 6

Determination of the dependence of tripping time t_{tr} of the RCCB (Q4) functionally independent of line voltage on the value of the residual current $I_{\Delta n}$ is carried out in the following sequence (a simplified scheme is shown in Fig. 8):

1) the handle of the autotransformer T1 is rotated counterclockwise until it stops;

2) the oscilloscope is connected to the RS2 terminals and set voltage 5V;

3) the handle of the switch S1 is set in the lower position;

4) the actuator of the switch S2 is set to the upper position - "I";

5) the handle laboratory autotransformer T1 slowly rotated clockwise to set the residual current $I_{\Delta n}$ according to the table. 6, controlling the current with a voltmeter PV, which is determined by the voltage U and the sum of the resistances of resistors R2 and RS2, which is equal to 1 kΩ;

6) the Q4 actuator is set to the upper position - "I";

7) press the button S4;

8) according to the oscilloscope to record the tripping time t_{tr} of Q4 (Fig.9).

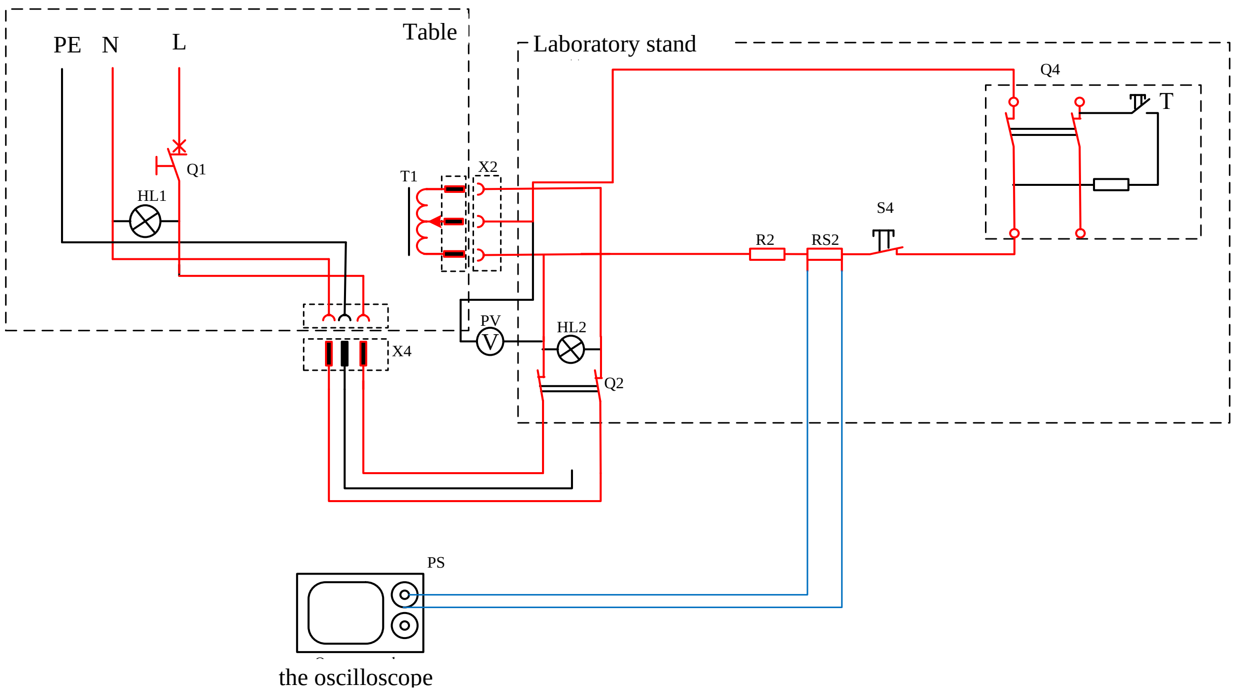

Fig. 8 – Simplified circuit for determination of the dependence of tripping time t_{tr} of the RCCB (Q4) functionally independent of line voltage on the value of the residual current $I_{\Delta n}$

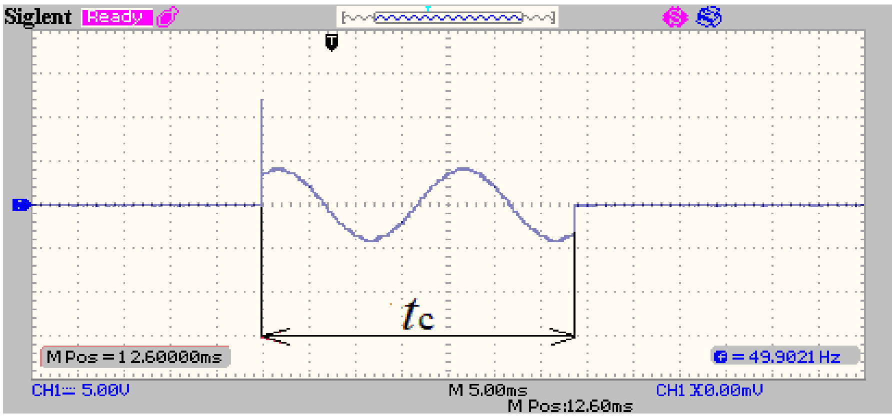

Fig. 7 – Oscillogram of current in the Q4 pole

Actions according to items 6 - 8 are carried out 10 times for each value of the residual current, writing the value of the tripping time of Q4 to Table 6. According to the determined data, calculate the average, minimum and maximum value of the tripping time. The table of determination of the dependence of tripping time t_{tr} on the value of the residual current $I_{\Delta n}$ must be included in the report. According to the table 6 build the functional dependence of the tripping time of the device (average value t_{tr}) on the value of the residual current $t_{tr} = f(I_{\Delta n})$.

After conducting experiments, perform the operations in the following sequence:

1) the handle of the autotransformer T1 is rotated counterclockwise until it stops;

2) the handle Q2 is set to the lower position - "0";

3) turn off the oscilloscope;

4) the handle Q1 is set in the lower position - "0";

5) disconnect X3, X4 from the socket on a stationary laboratory table (power supply of the laboratory stand and oscilloscope);

6) disconnect X1 from the corresponding socket on the stationary laboratory table (power supply of the amplifier Q3);

7) disconnect X2 from the corresponding socket on the stationary laboratory table (laboratory autotransformer T1);

8) disconnect the voltmeter.

Table 6 – The results of the experiment to determine the dependence of the tripping time t_{tr} of the RCCB (Q4) functionally independent of line voltage on the value of the residual current $I_{\Delta n}$

The experiment №	The value of the residual current I_{Δ} , mA					
	22	26	30	34	38	42
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Average value						
Minimum value						
Maximum value						

Test questions

1. Purpose of a residual current circuit-breaker.

2. The principle of operation of RCCB and RCBO.

3. What is the difference between RCCB and RCBO?

3. The elements of construction of a residual current circuit-breaker.

4. What are stationary and mobile residual current circuit-breakers?

5. What are the residual operating and non-operating currents?

6. What is the difference between functionally independent of line voltage and functionally dependent on line voltage residual current circuit-breakers?

7. How to check the functionality of a residual current circuit-breaker?

8. Standard values of rated residual operating current are: (6, 10, 30, 100, 300, 500) mA. Where are the devices with each of the residual current values installed?

9. Break time of a RCCB.

10. Difference between RCCB type A and type AC.

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