

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
Національний університет «Запорізька політехніка»

МЕТОДИЧНІ ВКАЗІВКИ

до виконання лабораторних робіт студентами
з англійською мовою навчання денної форми
на першому (бакалаврському) рівні вищої освіти навчання при
вивченні дисципліни

«Електричні апарати автоматики та керування»

для підготовки бакалаврів за спеціальністю

141 «Електроенергетика, електротехніка та
електромеханіка»

з подальшим навчанням за освітньою програмою

«Електричні та електронні апарати»

Частина 1

Методичні вказівки до виконання лабораторних робіт студентами з англійською мовою навчання денної форми на першому (бакалаврському) рівні вищої освіти навчання при вивченні дисципліни «Електричні апарати автоматики та керування» для підготовки бакалаврів за спеціальністю 141 «Електроенергетика, електротехніка та електромеханіка» з подальшим навчанням за освітньою програмою «Електричні та електронні апарати». Частина 1 / Укл.: Жорняк Л. Б., Антонова М. В., Войтенко С. В. – Запоріжжя: НУ «Запорізька політехніка», 2022. – 62 с.

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Затверджено
на засіданні кафедри
“Електричні і електронні апарати”.
Протокол № 1
від 29 серпня 2022 р.

Рекомендовано до видання
НМК ЕТФ.
Протокол № 1
від 8 вересня 2022 р.

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INTRODUCTION.

GENERAL REQUIREMENTS FOR THE EXECUTION, DESIGN AND PRESENTATION OF REPORTS ON THE LABORATORY WORKS

Electrical automation and control devices include various electronic and electromechanical relays, sensors and various executive devices (electromagnetic valves, couplings, converters, hangers, supports), command equipment (limit and limit switches, rotary switches, etc.).

Automation devices are low-current relays, sensors, amplifiers, converters, controllers, etc. widely used as means of automation in all branches of technology. They operate under conditions of low voltage (up to hundreds of volts) and currents (up to 5 A) and usually perform the functions of monitoring any electrical parameter (for example, relays) and non-electrical input parameter (for example, sensors). When the input (controlled) parameter of the relay reaches the set value, the electrical relay is activated and the output "signals".

The control devices are designed for frequent operational disconnections and inclusions of normal load currents and infrequent disconnections of load currents, which usually exceed the nominal ones by 5...20 times. To improve the conditions of current switching in control devices, sometimes semiconductor devices are used, which shunt mechanical contacts. In such hybrid devices, long-term current conduction is carried out by contacts, while semiconductor devices are actually de-energized.

Automatic switches, fuses, thermal relays, devices controlled by differential current are often divided into a separate group – protection devices.

The purpose of conducting laboratory work in the discipline "Electrical devices of automation and control" (EAA and K) is:

- deepening, expanding and consolidating students' knowledge of the main sections of the course, namely knowledge of the principles of operation and structure of the most common automation and control devices, as well as knowledge of the physical processes that occur during their work;
- study of laboratory stands of the auditorium of the EEA department, conducting research with electrical and electronic devices;
- study of the principle of operation and the structure of devices and devices, research of the physical essence of phenomena occurring in low-

voltage electrical devices in general, as well as in device diagrams;

- acquisition of testing and research skills of automation devices;
- improvement of processing skills and design of experiment results;
- the formation of students' skills and abilities, which will allow them

to design, manufacture and operate electrical automation and control devices in practice, and to use the acquired knowledge to create more modern and advanced electrical devices.

For all laboratory works, universal stands are used, which are equipped with mobile units for various laboratory works, which allows you to use them when conducting all laboratory works on the course. When performing all laboratory work, it is necessary to be attentive and comply with all the requirements of the teacher and technical staff of the laboratory related to the performance of laboratory work. It is also necessary to strictly observe the rules of safety and behaviour prescribed for laboratory premises of the university, as well as general norms of behaviour. Before performing the laboratory work, it is necessary to carefully familiarize yourself with the description of the laboratory work and the stand. Do not turn on the device without the permission of the teacher conducting the class. In case of detection of an abnormal situation (burning smell, appearance of smoke, sparks, etc.), it is necessary to turn off the QF automatic switch on the front panel of the stand and notify the teacher about it. Do not eliminate malfunctions that occurred during the work on your own. After finishing work, turn off the QF automatic switch.

Laboratory work can be carried out by students in the educational laboratory or remotely, as well as independent study of theoretical material in the recommended literature, which can be viewed at the links <http://eir.zp.edu.ua/handle/123456789/488> on the university website, or <https://zp.edu.ua/kafedra-elektrichnih-ta-elektronnih-aparativ> on the website of the EEA department. Active independent work is a determining factor in the effective perception of the content of laboratory classes.

The laboratory work execution consists of the student's work in the laboratory, as well as on independent work. Active independent work is a determining factor in the understanding of the laboratory work content.

Student's independent work involves:

- theoretical preparation;
- preparation of the answers to the questions, given in the end of each laboratory work;

- analysis of the experiments results that are carried out in the laboratory;
- report design.
- Theoretical preparation to the laboratory work involves:
- study of the theory sections that are determine the content and methodology of the research;
- study of the methodical instructions for the laboratory work using recommended textbooks and manuals;
- report design;
- student's work in the laboratory involves:
- admission to the laboratory work;
- admission to turn on the laboratory setup;
- steps execution with the investigated object in accordance to the methodical instructions; monitoring of the factors affecting the object; carrying to the experiments and recording of the measurement results;
- report presentation.

Reports on the laboratory works are prepared individually by each student in one notebook.

Each report of students must consist of:

- the purpose of the work, investigation object;
- task to the laboratory work execution;
- a circuit diagram of the experiment;
- tables of experimental data;
- graphs of dependencies built on experimental data;
- conclusions on work;
- answers to control questions.

The protection of reports on the performance of laboratory work is carried out by students or at the same time by a team (provided full-time education is provided), or remotely by each student personally in the system <https://moodle.zp.edu.ua> with his personal password, but the assessment of answers to control questions and quality each student receives the performance separately. Students who have not completed all laboratory work, or have not defended all reports on the completion of laboratory work provided for by the curriculum and work program of the academic discipline,

are not allowed to pass the test and the examine:

- presentation of the reports on the laboratory works is carried out by the group members at the same time, but the questions and the assessment of the performance quality are received by each student separately;

- students who have not presented two reports on the laboratory works are not allowed to the next one;

- students who have not executed or presented all the provided laboratory works are not allowed to credit and exam.

Remarks:

- the laboratory works in the laboratory are carried out according to the schedule approved by the vice-rector for academic affairs;

- missed works in the laboratory are carried out before the modular week according to the schedule approved by the head of the department;

- laboratory work experiments are carried out by the group members together.

1 LABORATORY WORK # 1

STUDY OF ELECTROMAGNETIC NEUTRAL RELAY OF DIRECT CURRENT

The duration of the laboratory session is 2 hours

1.1 The purpose of the work

The main purpose of the laboratory work is to study the principle of operation and design of a direct current electromagnetic relay, to determine the relay parameters (return coefficient, reserve, amplification, branching of circles), relay characteristics.

1.2 General notes

Relays are widely used in automatic control, monitoring, signalling, protection and switching devices. Depending on the physical nature of the controlling signal, relays are divided into electrical, thermal, mechanical, optical magnetic, acoustic, etc.

Electric relays respond to such electrical parameters as current, voltage, power, electric current, etc., or to temperature, amount of heat, etc. An electric relay is a device designed to perform jump-like changes in the output circuits at given electrical values that are in effect. An electromechanical relay is an electric relay whose operation is based on the interaction of the magnetic field of a stationary winding with a moving ferromagnetic element.

Electromagnetic neutral direct current relays are one of the main elements of automation, telemechanic, protection, etc. systems. With their help, the necessary interaction and sequence in the operation of individual parts of the system (devices, blocks, devices), protection, amplification, multiplication of circles, switching with a time delay or deceleration, fast-acting switching, etc. are carried out.

Figure 1.1 shows the simplest design of an electromagnetic relay with a closing contact and cantilevered contact springs. Here, the gap between the contacts is denoted as β , the gap between the pole and the armature as δ . And $\delta > \beta$. DC relays usually have a release pin (or non-magnetic gasket) to prevent the relay armature from "sticking" due to residual magnetization

from prolonged on-state operation. Sometimes, instead of a non-magnetic gasket, a bulge is pressed into the armature. In order to reduce the area of contact with the core (this does not affect the quality of the DC relay, since the value of the current does not depend on the gap between the armature and the core) in modern relays, an elastic polymer non-magnetic gasket is used.

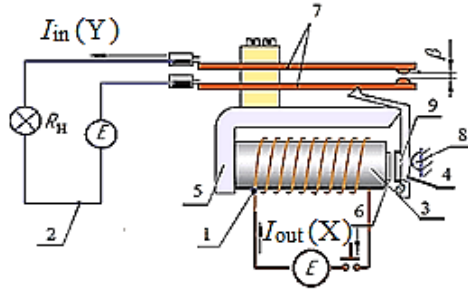


Figure 1.1 – Simplified design of an electromagnetic relay:

1 – winding of the control circuit; 2 – switching circuit (load); 3, 4, 5 – magnetic circle (3 – core, 4 – armature, 5 – yoke); 6 – pole tip; 7 – contact details; 8 – emphasis; 9 – a pin of unstickiness.

Relay elements are characterized by parameters related to input and output influences:

- operation is the minimum value of the influence (electrical signal) at the input, with such an increase, when the relay element changes its state and simultaneously affects the output in accordance with the relay characteristic;
- release is the minimum value of the influence (electrical signal) at the input, with such a reduction when the relay element returns to its initial state.

Due to the imperfection of the relay characteristic, these values usually do not coincide with each other (hysteresis loop). In some cases, the relay element can have the properties of fixation, i.e., remain in the state occupied by it even after removing the influence on the input. In this case, the relay element returns to its initial state usually after applying to another of its inputs (or applying the opposite sign of the signal to the same input) (Figure 1.2).

For the view of the relay characteristics or curve look the Figures 1.2. They have the output jump-in response increasing value $Y_{\max}$ at the any

electrical input value X (current, voltage, frequency, etc.), and a same jump-in reduce output value, but at another electrical input value. The output value is not change or small change at all other values of the input value.

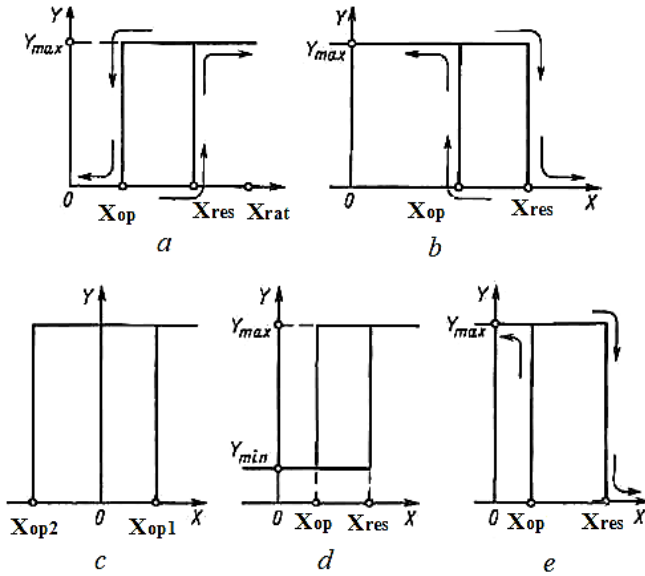


Figure 1.2 - Examples of the relay curves of different control devices which use the operating principle:

a, b, c, e – electromechanical; d – electrostatic;

a, b, d, e – one stabile; c – tow stabile;

a, b, d – maximal; e – minimal;

a, d, e – close switch operating; b – open switch operating.

X_{op} – is operating parameter; X_{res} – is reset out parameter (release);

X_{rat} – is rated parameter;

Y_{max}, Y_{min} – are maximal and minimal values of the output parameter.

Electromagnetic relays are divided into relays according to disposition of armature and its character of magnetic flux influence:

- a) with external unbalanced armature of valve type;
- b) with armature of solenoid type, which pull in it;
- c) with balanced armature and internal coil in it;
- d) with external balanced armature of return type, this pulls in.

The maximum value of such influence during its growth, which causes the return of the relay element to its initial state, is called the return parameter. The ratio of the release parameter and the activation parameter is called the *release coefficient* (reset):

$$K_{res} = \frac{X_{res}}{X_{op}} - \text{is the reset ratio (return coefficient);}$$

The closer the value of the return coefficient is to unity, the more narrowly the relay will control the input parameter ($K_{res} < 1$).

The operating value of the impact value X_{rat} – is the maximum value under which the sensing element can be exposed for a long time without overheating (destroying).

The *safety factor* – is the ratio of the rated and operating values of relay:

$$K_s = \frac{X_{rat}}{X_{op}} - \text{is the safety factor over actuation;}$$

The closer the value of the return coefficient is to unity, the more narrowly the relay will control the input parameter ($K_s > 1$).

The operating value of the impact value (rated parameter) X_{rat} – is the maximum value under which the sensing element can be exposed for a long time without overheating (destroying).

The coefficient of multiplication of circuits K_c – is the ratio of output circuits (number of contact pairs) and input circuits (number of coils, or control circuits):

$$K_c = \frac{n_{outp}}{n_{inp}} - \text{is the circuit multiplication coefficient;}$$

The characteristic of the relay element is also the *speed of operation*, which is determined by the time of activation and the time of release or return. In some cases, the important characteristics of the relay element are: energy consumption, weight, occupied volume, etc.

Operating power (output) P_{outp} – is the power consumed by the relay when it is operated.

Control power P_{contr} – is the electrical power of the output circuit that the actuator can pass for a long time corresponding to Y_{max} . In contact relays, this is the power that the contacts will be able to switch at the rated voltage.

The coefficient of amplifier – is the ratio of control power to operating power.

$$K_{ampl} = \frac{P_{outp}}{P_{op}} - \text{is the amplification coefficient.}$$

The output power is calculated by the next formula

$$P_{outp} = U_{cop} \cdot I_{ccl};$$

where U_{cop} – is the voltage on contacts before closing ($U_c = 220V$);
 I_{ccl} – is the current of commutation circuit ($I_{ccl} = 5A$).

1.3 Steps of work execution

Before execution student have to:

- to study corresponding methodical recommendation and repeat the chapter about relays of DC current;
- prepare the table 1.1;
- connect the circuit (Figure 1.3);
- after checking circuit by lecturer step up and down voltage and measure following values: $I_{op}, U_{op}, U_{res}, I_{res}, I_{rat}, U_{rat}$, then fill in the Table 1.1 with data;
- calculate coefficients:

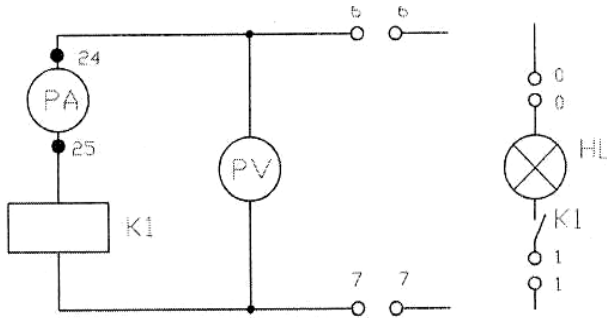


Figure 1.3 – Principal circuit of testing

Table 1.1 – The results of measurements and calculations

# of testing	Measurements						Calculations			
	I_{op}, A	U_{op}, V	I_{res}, A	U_{res}, V	I_{rat}, A	U_{rat}, V	K_s	K_{res}	K_c	K_{ampl}
1										
2										
3										
Average values										

1.4 Safety method instruction

To do all connections of principle circuit of laboratory stand at opening switch SF!

Clearly follow safety methods instruction and internal order rules.

1.5 Control questions

1.5.1 Give the definition of the electrical relay, electromechanical relay, and electromagnetic relay.

1.5.2 Purpose, definition of relays and field of their application.

1.5.3 Give the definition of the coefficients K_s , K_{res} , K_c , K_{ampl} .

1.5.4 What kinds of magnetic system are used in DC current electromagnetic neutral relays?

1.5.5 The definition of operation, release, rated, admissible values.

1.5.6 What parameters are used to define quality of relay, its sensitive and hysteresis qualities?

1.5.7 What do the opposing, loading and tractive characteristics mean?

1.5.8 What does displacement of opposing and tractive characteristics mean?

1.5.9 Tell the view of the relay characteristic and its hysteresis view.

2 LABORATORY WORK # 2

STUDY OF ELECTROMAGNETIC RELAY OF ALTERNATIVE CURRENT

The duration of the laboratory session is 2 hours.

2.1 The purpose of the work

The main purpose of the laboratory work is to study principle of operation, desing and main assemblies of electromagnetic relay PT-40; to define the basic technical parameters & relay characteristics.

2.2 General notes

The maximal current relays are used in the control relay devices and anti-emergency automation. They react on the increase of current. One of varieties of the electromagnetic systems is used in the relay of PT-40 series, called by the system with transverse motion of armature (Figure 2.1). The magnetic system of relay consists of Π -type laminated magnetic core 5 and the G-type armature 3, rotated on two semiaxes 6. The armature of relay is hold in initial position by a counteractive spiral spring 7, one end of which is related to the armature, and other with the pointer of setpoint 8. The counteractive moment of spring and accordingly operating current of relay are changed at the rotation of pointer of setpoint. Necessary position of pointer is determined by divisions calibrated on a scale 9. At armature a plastic block 10 is mounted with a moving contact bridge 11. At high part of bracket 2, related to the armature, a hollow drum is mounted 1. A drum has inside radial partitions and filled by dry quartz sand. On the magnetic core the coils 4 are located. Those ends are out on the clamps of base of relay. On these clamps it is possible to carry out transposition of bridges into parallel and series connections of coils and accordingly to change the value of operating current settings in two times. Numbers, calibrated on a scale, correspond to series connection of coils. All of elements of relay are mounted on a scope made from an aluminum alloy, fixed on a plastic base and closed by the transparent housing.

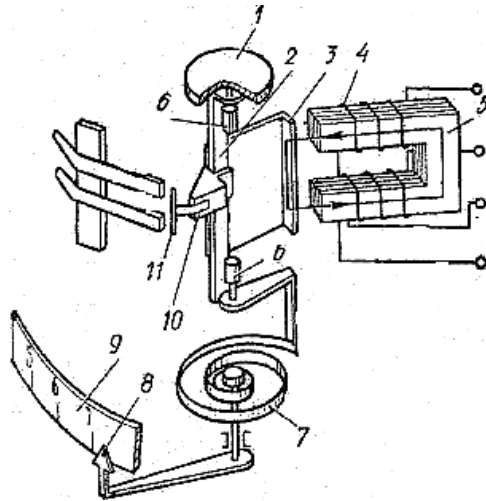


Figure 2.1 – Sketch of mechanical scheme of PT-40 relay

At carrying out of current on the winding of relay a magnetic flux which is locked through core and armature is created. A flux, passing an armature, magnetizes it. Electromagnetic force, proportional to the square of magnetic flux, attracts an armature to the poles of core; the contacts of relay are closed at this moment.

Rotating angle of relay armature 2 is limited by supports 1 and 3 (Figure 2.2). If the right support 1 is absent, under the action of electromagnetic moment an armature will turn on the angle of 90° . It will be corresponded to maximum value of magnetic flux in an air-gap. Thus, an electromagnetic moment will be equal to the zero.

For providing of necessary pressure on contacts the relay operation must be carried out in the certain limits of angles of armature rotations. For the PT-40 relay the angles of armature rotations are set approximately 60° in initial position and 75° in eventual position of armature (α_H and α_K in the Figure 2.2).

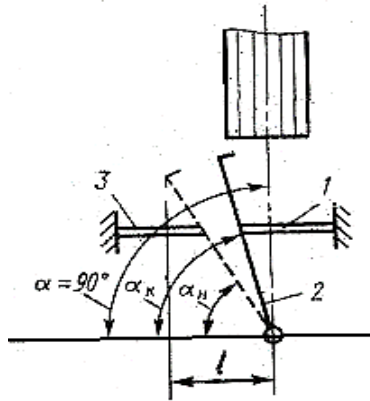


Figure 2.2 – The positions of armature under poles of relay

Thus, construction of relay has a high coefficient of reset ratio – about 0,8. The coefficient of return is name attitude of parameter of return toward the parameter of wearing-out

2.3 Steps of work execution

Before execution student have to:

- to study corresponding methodical recommendation and repeat the chapter about AC relay;
- prepare the table 2.1 (for parallel and series connections of coils);
- connect the circuit (Figure 2.3) for parallel and series measurements;
- after checking circuit by lecturer step up and down voltage and measure values: I_{op} , I_{res} at different values of operating current settings $I_{op rat}$, than fill in the Table 2.1 with data (such measuring to do for parallel and series);
- to calculate the reset ratio of relay K_{res} ;
- to plot functions $I_{op} = f(I_{op rat})$, $I_{res} = f(I_{op rat})$, $K_{res} = f(I_{op rat})$.

2.4 Safety method instruction

Clearly follow safety methods instruction and internal order rules.

[illegible]

2.5 Control questions

2.5.1 Give the definition of the alternative current relay, details of construction at opposite to direct current relay.

2.5.2 What types of relays are used at alternative current circuits?

2.5.3 What cause of core vibration of alternative current relays?

2.5.4 What methods of liquidation of core vibration of alternative current relays?

2.5.5 What constructive methods of liquidation of core vibration of PT-40 relay?

2.5.6 Give the construction of PT-40 relay.

2.5.7 What difference between closings of the alternative current relay and direct current relay?

2.5.8 How is operating current setting regulate?

3 LABORATORY WORK # 3

STUDY OF THE POLARIZED RELAY

The duration of the laboratory session is 2 hours.

3.1 The purpose of the work

The main purpose of the laboratory work is to study principle of operation, desing and main assembles of electromagnetic relay PT-40; to define the basic technical parameters & relay characteristics.

3.2 General notes

The polarized relays are electromagnetic relays operation of which depends on value of input signals and initial polarization. Opposite to neutral relays the core motion of polarized ones depends on current carry direction at operating winding. There are polarized with series, differential and bridge circuit flux circuits.

Modern polarized relays most often have two or more coils, thus perhaps more flexible designing of electric circuits, controlling of varying polarity currents and use of these devices, not only as switching, but logical elements. Structures of modern magnetic system of polarized electromagnetic relays designed on the principle of differential or bridge circuits.

There is one-stabile and two-stabile polarized electromagnetic relays. They also are differed by type of adjustment.

At two-stabile neutral adjustment of relay the contact assembles are installed symmetrically on a neutral line, which is one of the axes of symmetry magnetic system relays. Armature is then transferred from one its extreme stabile state to another one (with the implementation of switching relay circuits by contact assembles), at the same modules of magnetomotive forces (MMF) in winding (or windings). Armature and, consequently, contact assemble are found in the position in which they were the before the current supply in the winding (windings). Such relays are called two-stabile two-position (bang-bang control).

At two-position adjustment (bang-bang control) with domination (biasing) each contact assembles are located on one side from neutral, but

at different distances from it. Operation of such relays occurs only at certain direction of currents in the winding (windings). After switching off currents armature always is returned to the same initial stable position. At that moment contact assemblies commute the relay output circuits in reverse order. Such relays operate as a sensitive neutral electromagnetic relay, and therefore are one-stable ones.

At three-positional adjustment contact assemblies are located the same as in two-position neutral adjustment (bang-bang control) that is symmetrically relatively neutral of magnetic system. But at the absence of current in the winding (windings) armature of the relays with three-positional adjustment takes a neutral (average) stable position cause effort of opposing strength spring often is a suspension. Due to current carrying through the windings in the same direction the armature initiates contact one of the switching assemblies. At direction current changing the armature deviates from the other side of its neutral and make the second contact switching assemble. The operate currents in both directions, as well as from two-position relays with neutral adjustment, will be practically identical. Such relays are called one-stable three-positional adjustment ones.

Structures polarized relays are different. In laboratory work three relays (PII-4, PII-5, PII-7) are the objects of testing.

During operation of the relay, the armature can occupy several positions, and in two-position regulation with predominance, the armature is always in one position, if there is no current in the working winding. Predominance can be provided either by adjustment or mechanically, for example, by a spring. In a two-position relay without predominance, in the absence of current in the working winding, the contacts (armature) are located near one of the two contacts (poles), and this depends on the previous direction of the current in the winding.

Operation occurs after a change in the direction of the current relative to the forward state. The armature of the three-position relay (in the absence of current in the working winding) is in the middle position. When the trigger signal is applied, the armature moves either to the left or to the right depending on the direction of the current [1, 2, 3]. This is achieved by fixing the armature on a sufficiently stiff suspended return spring (Figure 3.1, a).

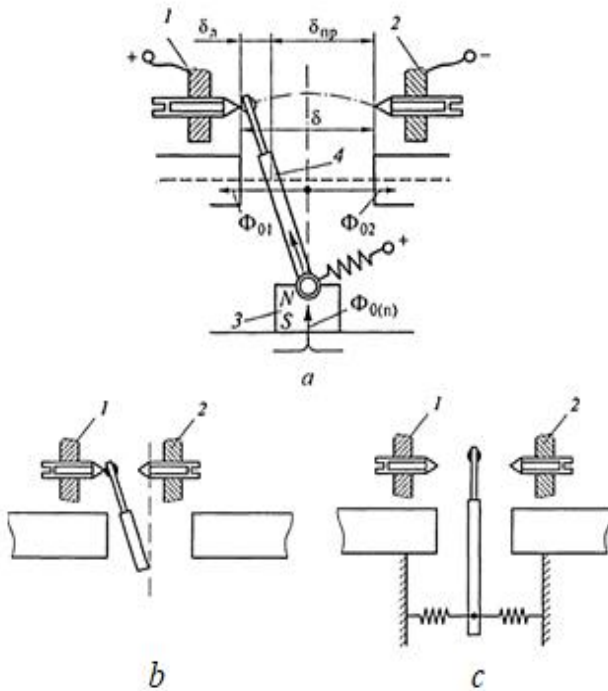


Figure 3.1 – Schematics of setting the contacts of the polarized relay:

a – two-position; *b* – two-position with the predominance of one of the contacts; *c* – three-position.

The relay, the contact system of which is shown in Figure 3.1, is two-position. If its fixed contacts 1 and 2 are symmetrically located relative to the neutral line (the armature is adjusted symmetrically), then when the control signal is removed, the relay armature remains in the same position it occupied in the presence of the control signal. Repeating the signal of the previous polarity does not cause a change in the position of the armature. If you change the polarity of the control signal, the armature will flip to another position and will remain in it after removing the signal. This setting is called neutral, or two-position. If one of the contact screws is pushed beyond the neutral line (Figure 3.1, *b*), then the relay is two-position with the predominance of one of the contacts. In the

case shown in the figure, when the relay is turned off, the armature is always pressed to the left contact, i.e., contact 1, and is overturned to the right only during the current flow of the corresponding polarity in the control winding.

The three-position relay has fixed contacts (Figure 3.1, c) 1 and 2 (left and right, respectively) symmetrically located from the neutral line. An armature that, in the absence of a control signal, is held in the middle position by means of special springs located on two sides, or fixed on a flat spring, the elasticity of which creates a stable equilibrium position in the middle position. When a signal is applied to the control winding, the contact on the armature closes depending on the polarity of the signal with a left or right fixed contact and returns to the neutral position after the signal is removed.

Designs of polarized relays in industry are different.

In laboratory work, the objects of testing are three types of relays (RP-4, RP-5, RP-7), which are used for switching electrical circuits in automation equipment, communication (in the receiving and transmitting circuits of tone telegraph equipment) and signalling. Relays can be used in moving devices. Relays differ in the regulation of contact systems:

- RP-4 and RP-4M – are two-position, neutral, two-stable;
- RP-5 – is three-position, monostable, the relay armature of the RP-5 type, in the absence of a violation, is in the middle position and touches the contacts;
- RP-7 – is two-position, monostable, with a preference for the right contact. In the absence of current in the winding, the armature of the RP-7 type relay is always pressed to the right contact.

The RP-4M relay has a fluoroplastic gasket between the armature springs. The gasket is designed to reduce the rattling of the anchor. The RP-5 type relay differs from the RP-4 type relay by the greater thickness of the suspension armature spring. The magnetic circuit of relays of RP types is built according to the bridge scheme, in which the paths of constant and control (alternating) magnetic fluxes are separated. The controlling magnetic flux is directed across the armature.

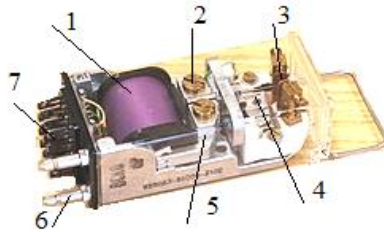


Figure 3.2 – Design of polarized automatic relays RP-4, RP-5 and RP-7 [3]

An L-shaped permanent magnet made of aluminium-nickel steel together with a pole tip (shoe) made of mild electrotechnical steel of the EA brand is poured into the aluminium base of the relay. A magnetic wire in the form of an open rectangle 5 assembled from sheet molybdenum permalloy is screwed to the tip with two screws 2. On the core there is a coil 1 made of black monolith, on which from one to seven windings are wound. The anchor of relay 4 is riveted from two plates of mild electrotechnical steel and fixed (suspended) on a thin steel spring in aluminium frame. To stabilize the position of the anchor, the suspension spring is stretched. Two tin-phosphorus bronze contact springs with contacts are riveted to the anchor. The armature and contact system of relay 3 are assembled on a separate ceramic base. The Silumin frame with an anchor is screwed with two screws to the ceramic base, on the other end of which two contact racks with fixed contact springs and adjusting screws are attached.

The contacts have a spherical contact surface. Material of relay contacts PDCRKH-1, VS-70 (for relay execution PB4.522.000-01 – ZINk95-5 material). The ends of the windings and the circuits of the contact system 7 are soldered to 16 flat contact pins (lamellas) of a special plug block made of phenoplast. This pad is attached with two screws and two pins directly to the Silumin base (case). The inclusion of the relay in the power supply circuit and switched circuits is carried out using the connecting (plug) block 6, which allows quick replacement of the relay. Relays work reliably at a current that exceeds 2-4 times their tripping current. The working position of the relay is any. According to the number of windings, the relay can be: – RP-4 two-winding, three-winding, seven-winding; – RP-5 single-winding, two-winding, three-

winding, four-winding, five-winding, six-winding and seven-winding; – RP-7 single-winding, two-winding, three-winding, four-winding, five-winding and seven-winding. Polarized relays are widely used in automation circuits due to their characteristic features, namely, the presence of several windings allows them to be used as logic elements, small triggering power - as control elements of small electrical signals, short triggering time and sensitivity to the polarity of input signals - as amplitude modulators and demodulators. Due to their high sensitivity, polarized relays are often used in low-power alternating current circuits, turning them on through a rectifier [3].

3.3 Description of the laboratory stand

The electrical test circuit consists of a standard power source based on all laboratory tables and panel-mounted laboratory equipment. This is shown in Figure 3.3. The voltage polarity of the relay windings is changed by switch S3. Connection of any relays (RP-4, RP-5, RP-7) is carried out by switch S4. The measurement range of millimetres PA is changed by switch S2, and its values are fixed by button SB. Lamps HL1 and HL2 must be connected with short conductors to indicate the position of the contacts of the test relays.

3.4 Steps of work execution

Before execution student have to:

- to study corresponding methodical recommendation and repeat the chapter about polarized relays;
- prepare the tables 3.1 and 3.2;
- connect the circuit (figure 3.1);
- after checking circuit by lecturer step up and down voltage and measure following values: I_{op} , U_{op} , U_{res} , I_{res} , I_{rat} , U_{rat} , then fill in the Tables 3.1 and 3.2 with data for all types of relays;
- plot the relay control characteristic.

To study types of PII 4, PII 5, PII 7 relay adjustments and polarity of them contacts it is necessary:

- a) switch S3 put on position “0”;

- b) switch S4 put on position of testing relay;
- c) put autotransformer T at zero station, switch on SF, control lamp HL;
- d) set voltage value 220 V by device PV2 (look a circuit on laboratory stand);
- e) setting switch S3 into positions according table 3.1 fix a contact position (according to lamping of HL1 and HL2);
- f) repeat point (e) for all types of relays, after that put autotransformer T at zero station.

Carry out measurements, for which, with the S3 key open, set the voltage to 3 V using the autotransformer T. At the same time, set the required measurement limit with the switch. With the help of S3, switching to the positions indicated into the Table 3.1, determine the type of relay adjustment, noting in Table 3.1 the illumination of the left (L) or right (R) signal lamp.

Set the autotransformer T to the position corresponding to zero. Set the switch S2 to the 100 mV or 300 mV position, set S3 to the "+" position. Turn on winding 1 with switch S4 and, gradually increasing the voltage with the help of autotransformer T, record I_{op} and U_{op} of the relay at the moment, when the left one – is off and the right – is on (or vice versa). Relay contacts have been switched.

If the relay did not switch when the voltage increased to 3 V, then it is necessary to bring the autotransformer to zero, set S3 to the "-" position, and repeat the experiments for each type of relay. By reducing the voltage using T, fix I_{res} and U_{res} of the relay according to the change in the lighting of the signal lamps (for the corresponding types of regulation). Determine the values of K_{res} , K_s , K_c and K_{ampl} (look 1st laboratory work).

Build the relay characteristic of each type of relay.

Table 3.1 – Testing data

Type of relays	# windings	The contact positions of switch S3								Type of adjustment
		0		1		0		2		
		HL1	HL2	HL1	HL2	HL1	HL2	HL1	HL2	
PII-4	1									
	2									
PII-5	1									
PII-7	1									

To testing operate and reset currents and voltages of relays and to plot of their control curves it is necessary:

- switch S4 put on position of testing relay;
- switch S3 put on position “1” and fix all need parameters by PV and PA (push button SB);
- put autotransformer T at zero station, switch S3 put on position “2” and fix all need parameters by PV and PA (push button SB);
- fill experimental data into table 3.2 for all types of relays;
- after all testing switch off SF, disconnect laboratory circuit.

Table 3.2 – Testing data

Type of relays	Position of switch S3		Parameters of relays					
			I_{op}, A	U_{op}, V	I_{res}, A	U_{res}, V	P_{op}, W	K_{res}
PII-4	1	1						
		2						
	2	1						
		2						
PII-5	1							
	2							
PII-7	1							
	2							

To calculate the reset ratio (return coefficient), amplification

coefficient at condition of power of circuit commutation of all testing relays is equal to 4,8 W.

3.5 Safety method instruction

To do all connections of principle circuit of laboratory stand at opening switch SF!

Clearly follow safety methods instruction and internal order rules.

3.6 Control questions

3.6.1 Answer difference between the polarized relays and neutral ones?

3.6.2 What advantages of the polarized relays at difference of neutral ones?

3.6.3 Answer principle of operation of the polarized relays?

3.4.4. What cause of more high speed of response and of the polarized relays at difference of neutral ones?

3.6.5 What types of adjustment of the two-position polarized relays?

3.6.6 What are types of magnet circuits used in polarized relays?

3.6.4. Чим пояснюється більш висока швидкодія і чутливість поляризованих реле у порівнянні з нейтральними?

3.6.5. Які існують типи налаштування двопозиційних поляризованих реле?

3.6.6. Які типи магнітних кіл використовуються у поляризованих реле?

4 LABORATORY WORK # 4

STUDY OF REED RELAY

The duration of the laboratory session is 2 hours.

4.1 The purpose of the work

The purpose of work is to study the concept of operation, design and main assemblies of reed relay, to investigate parameters of operation and response, distinctive features of operation of several magnet control (MC) in one control winding.

4.2 General notes

Electromagnetic contactor is an element of electric circuit, which changes its state with the help of mechanical closing and opening thanks to the influence of control flux on the contact of this element, which combine functions of electric and magnetic circuits.

Encapsulated magnetic (reed) contact is a magnetic control contact, details of which are enclosed from environment.

Reed relay are most often represented as coils, in center of which one or more reeds are placed.

Contacts are bridged or opened when the magnetic field is missing. If direct-axis magnetic field takes place springs bend and make contact or open contact details. Thanks to encapsulation of contacts the reliability of commutation and stability of transition resistance are improved in comparison with non-encapsulated contact devices. Term of service is about 10^6 - 10^9 commutations, time of operation is 5,0 - 2,0 ms, time of return is 0,2 - 1,0 ms.

Disadvantages of reed relays are low computational current; the necessity of reliable screening from external magnetic fields and others.

Hermetic contact (sealed contacts) is widely used in the automatic-control system, control systems, computers, relays, logical elements, voltage and current transformers, transducers of non-electric values, coaxial contractors, switches, operating elements of circuit s of frequency conversation in HF-devices, end breakers.

Hermetic contacts (sealed contacts) can be classified according to:

- a) character of ferromagnetic electrode in magnetic field interaction;
- b) magnetic circuit configuration;
- c) type of the contact group;
- d) ferromagnetic electrodes material;
- e) type of electric contact;
- f) type of envelope;
- g) variety of moving system;
- h) type of encapsulating;
- i) overall value and etc.

According to hermetic contacts (sealed contacts) construction design, they can operate several magnetic fields, variable of magnetic circuit characteristic. At operation of several hermetic contacts in one operating coil contacts are closed (opened) not simultaneously, the first the most sensitive hermetic contact are closed (opened), and then the others. Each commutation of hermetical contacts is followed by rearrangement of magnetic flux in the coil. The reed relay is considered to have operated when all of the contacts are closed (opened), and not operated when all of the contacts are opened (closed).

In the classic design, the reed switch is a glass cylinder 1 (note that the glass of reed switches is usually green in colour due to the presence of iron ions, when the glass cylinder is welded using infrared radiation or resistance welding), into which contact parts 2 are soldered (since they combine several functions, they are also called contact cores - KO), made of a magnetic alloy with high magnetic permeability (most often from permalloys) and 3 terminals (Figure 4.1). This reed switch is located in the control circuit - coil 4. Permalloy are alloys of iron and nickel, which have a large initial magnetic permeability in the region of weak magnetic fields, which is associated with the practical absence of anisotropy and magnetostriction. The commutating parts of the contact parts are covered with a layer of noble metals ($RP = \text{const}$), such as rhodium Rh, gold Au and their alloys. Either a vacuum is created inside the glass cylinder, or the cylinder is filled with dry gas (nitrogen N, hydrogen H, or their mixture), which do not enter into a chemical reaction with the contact material. If the reed switch is placed in a magnetic field created by an electromagnetic coil, an electromagnet, or a permanent magnet, a certain magnetic flux passes through the contact parts [3].

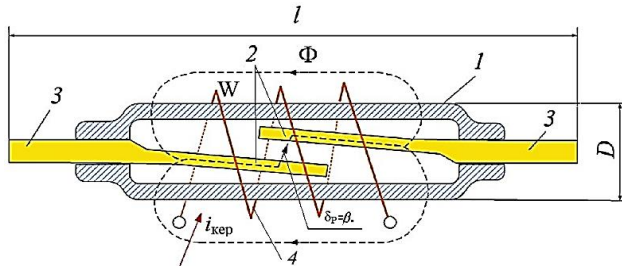


Figure 4.1 – Design of a symmetric magnetically controlled closing contact (reed switch) [3]

4.3 Steps of work execution

Before execution student have to:

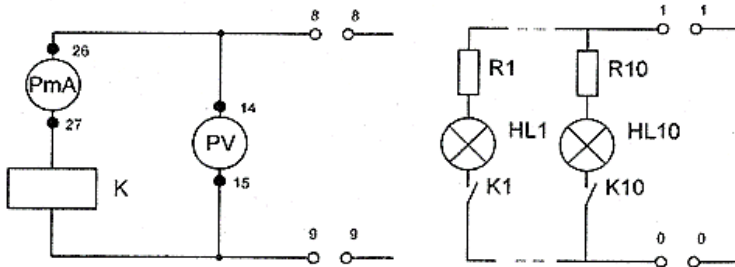
- study corresponding methodical recommendation and repeat chapter about relay of reed relays;
- prepare the Table 4.1;
- assemble the circuit (Figure 4.2);
- experimentally find out min, maximal and average values of currents, voltages, e.m.f. and energy of operation and reset of PИИ relay, and also operating current in the control circuit;
- having all these values plot the controlling characteristic of PИИ relay (dependence of circuit load voltage on current in control circuit), for this case:
 - deduce transformer T to zero value;
 - to switch on SF, slowly rising a voltage of power according to lamps HL1.HL10 fix and write down the values of current and voltage of winding up to rate one (12V) and write down operating current;
 - lowering voltage on relay winding, according to lamps fading fix and write down reset current and voltage of each hermetic contact;
 - deduce transformer T to zero value; fill in the Table 4.1 with the obtained values.

The operating and resetting forces of each contacts F_{op} and F_{res} are calculated by such formulas:

$$F_{op} = I_{op} \cdot W_{coil} ;$$

$$F_{res} = I_{res} \cdot W_{coil} ,$$

where W_{coil} – is number of turns in coil of reed relay.



Picture 4.2 – Principal circuit of switch on hermetical contact relay

4.4 Safety method instruction

All commutation of the circuit to execute at switch QF turned off.
Clearly follow safety methods instruction and internal order rules.

4.5 Control questions

- 4.5.1 What is magnetic hermetic contact (sealed contacts)?
- 4.5.2 Basic construction designs, purpose and fields of appliance of MC.
- 4.5.3 What materials are used to make hermetical contact (sealed contacts)?
- 4.5.4 When does smoldering discharge of hermetical contact (sealed contacts) use?
- 4.5.5 Give the definition of ferrite.
- 4.5.6 When does the MC control with the help of magnetic fields use?
- 4.5.7 Explain the property of AC relay operation on hermetical contacts (sealed contacts).
- 4.5.8 What is the difference in ferrites with insert memory?
- 4.5.9 What methods are used to prevent “false” operation of ferrite?

4.5.10 Peculiarities of operation of several MCs in one control winding.

Table 4.1 – Measured and calculated values (for 11 measurements)

[illegible]

5 LABORATORY WORK # 5

STUDY OF VARIABLE-CAPACITANCE TRANSDUCER

The duration of the laboratory session is 2 hours.

5.1 The purpose of the work

The purpose of work is to study the principle of operation, design of variable-capacitance transducers, calculate and determine experimentally parameters of the transducer, to compare experimental and computational data, to do conclusions.

5.2 General notes

In the variable-capacitance transducers the change of the measured value is proportional change in the condenser capacity.

If to analyze the expression that determines the capacity of the flat capacitor:

$$C = \frac{\varepsilon_a S}{d},$$

where ε_a - is the absolute dielectric permittivity;

S – is the square capacitor plates;

d – is the distance between the plates,

it can build three types of transducers by principles (figure 5.1):

- a) the principle of changing the distance d between the electrodes -- displacement transducers;
- b) the change of the square of the rotation angle transducer;
- c) changing of dielectric permittivity ε_a - that is a level transducer (detector).

Structurally variable-capacitance transducers are made with flat, cylindering, rotary, etc.

As an insulator used an air, mica, porcelain insulators, etc., as well as insulating liquids.

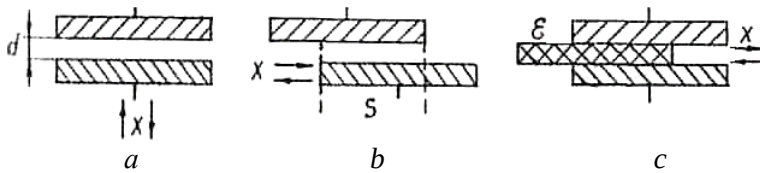


Figure 5.1 – The types of variable-capacitance transducers

In this laboratory work the variable-capacitance transducer is studied transducer of angle displacement. In the circuit of the transducer (Fig. 5.2) is used rotary air-dielectric capacitor. These variable capacitors are used in radio engineering to tuned circuit tunings.

To increase the capacity, they are designed multiplied ones. The operating square of capacitor plates depends on the rotation angle.

The capacity of the capacitor is changed at changing of the operating area of plates. Therefore, condenser resistance of alternating current and output parameters of the transducer U_{out} and I_{out} are changed. According to measuring instrument can understand state of input (control) value.

The advantages of variable-capacitance transducers are:

- a) the high sensitivity that allows to measure the rapidly - variable processes (vibrations, acceleration);
- b) the relatively small value s and weight;
- c) low inertia;
- d) a small opposite effect on the parameter;
- d) a small value of energy of interaction between the plates;
- e) low input effect.

The disadvantages of variable-capacitance transducers are:

- a) the need for high-frequency power supply;
- b) the need for shielding of external electric fields and parasitic capacitors;
- c) low power output caused by the large capacitive resistance X_c , due to low-capacity condenser;
- d) the effect of humidity and temperature on the value of its dielectric permittivity.

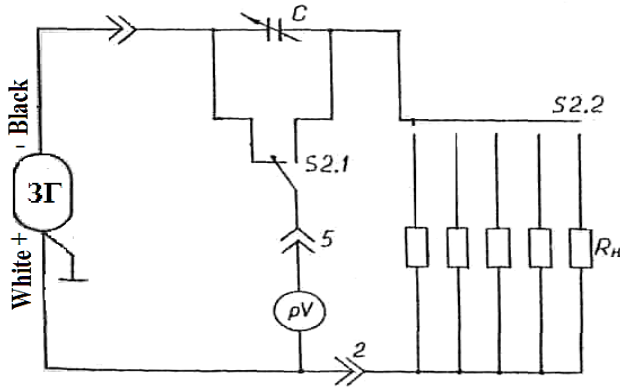


Figure 5.2 – The circuit of transducer testing

5.3 Steps of work execution

- to view the structure, scope of variable-capacitance transducers, their advantages and disadvantages;
- to calculate the maximum capacity of the condenser, used to test the transducer;
- to calculate the transducer capacitive reactance at various states of the capacitor rotor (0, 45, 90, 135, 180 °) and at different frequencies of the supply voltage (4, 7, 10 kHz).
- to calculate the current in the transducer circuit and the voltage at its output at $R_H = R_{H \max}$ of the above mentioned of the capacitor rotor states, and values of frequencies; analogically do such calculations at $f=4$ kHz, $R_H = (R_{H \min}, \dots, R_{H \max})$, $C = (C_{\min}, \dots, C_{\max})$
- for points, calculated in point 4, to determine experimentally $U_{\text{out}} = \varphi(f)$ and $U_{\text{out}} = \varphi(R_H)$;
- to calculate the sensitivity and to plot the experimental functions;
- to compare the results and do the conclusions.

5.4 Safety method instruction

All commutation of the circuit execute at switch QF turned off. Clearly follow safety methods instruction and internal order rules.

5.5 Methodical guide

5.5.1 Information about the variable-capacitance transducers can be found in the literature [1, 2, 3].

5.5.2 To calculate the maximum capacity of the condenser is necessary to measure the value of air gap between the plates and their operating square. The capacity of a flat capacitor is calculated by

$$C = \frac{\varepsilon_b \cdot \varepsilon_0 S(n-1)}{d} + C_0, \quad (5.1)$$

where $\varepsilon_b = 1$ – is a permittivity of air;

$$\varepsilon_0 = 8.85 \cdot 10^{-12} \text{ F/s};$$

S – is an operating plate square, m^2 ;

d – is the average gap between the plates, m ;

n – is the number of plates (fixed and mobile);

C_0 – is the minimum capacity of the condenser, equaled to 10% of first value in formula (5.1).

5.5.3 Capacitive reactance is calculated for the rotor states 0° ($C_{\min}$); 45° ($C=C_{\max}/4$); 90° ($C=C_{\max}/2$); 150° ($C=2/3 C_{\max}$); 180° ($C=C_{\max}$) at the frequency of supply (input) voltage $f = 4, 7, 10$ kHz. The calculation results are recorded in the table 5.1. (the calculation formula 5. 2).

$$X_c = \frac{1}{2\pi f C}. \quad (5.2)$$

5.5.4 The current of transducer circuit is calculated for values capacitance and resistance at different loads.

First of all, current in the transducer circuit is calculated at $R_H = R_H \max$, $f=4$ kHz the and values of C ($C_{\min}$, ..., $C_{\max}$). Then the same calculations are performed for other frequencies: 7, 10 kHz. Resistance of load is maximized. The results are recorded into table 5.2. According to get data are plotted functions $I = \varphi(f)$.

Table 5.1 – Data of calculations

α , grad	F, kHz				
	1	2	4	7	10
0					
45					
90					
135					
180					

In the second case, the frequency was adopted constant $f = 4$ kHz, the values R_H and C are changed. The results are recorded in the table. 5.2. To plot functions, $I = \varphi(R_H)$ according to the got data.

Knowing the current in the transducer circuit, it can calculate the voltage drop in the load resistance. This will be functions $U_{out} = \varphi(f)$ and $U_{out} = \varphi(R_H)$; and the results are recorded in the table 5.2. According to got data to plot functions $U_{out} = \varphi(f)$ and $U_{out} = \varphi(R_H)$.

$$I = \frac{U_{in}}{\sqrt{X_C^2 - R_H^2}}. \quad (5.3)$$

5.5.5 The voltage of the transducer input and its output is measured by one and the same voltmeter. At measuring of the input voltage switch S2.1 put in the position U_{in} at measuring of the output voltage - into U_{out} state.

For the experimental determination of function $U_{out} = \varphi(f)$ set up the frequency $f = 4$ kHz, voltage $U_{in} = 50$ V, $R_H = R_{H \max}$; changing the capacity of the condenser, register a value of U_{out} .

$$U_{out} = I \cdot R_H. \quad (5.4)$$

The same to done at other frequencies, supporting $U_{in} = 50$ V. Then, at $U_{in} = 50$ V and $f = 4$ kHz experimentally determine the dependence of $U_{out} = \varphi(R_H)$; changing R_H by switch S2.2. The results add to the table 5.2.

5.5.6 According to a known data and the formulas to calculate the sensitivity of variable-capacitance transducers (Kt).

$$K_T = \frac{\Delta U_{out}}{\Delta C}. \quad (5.5)$$

5.5.7 Plot calculated and experimental dependences $U_{out} = \varphi(f)$, $U_{out} = \varphi(R_H)$, $K_t = \varphi(f)$, $K_t = \varphi(R_H)$.

5.6 The content of the report

5.6.1 The aim of this work.

5.6.2 Circuit of the apparatus testing.

5.6.3 The tables and graphs.

5.6.4 The calculation formulas.

5.6.5 Analysis of the calculation results and experiment.

5.6.6 Conclusions.

5.7 Control questions

5.7.1 What are the principles of variable-capacitance transducers?

5.7.2 What are examples of structures of variable-capacitance transducers?

5.7.3 What used variable-capacitance transducers?

5.7.4 Advantages and disadvantages of variable-capacitance transducers.

5.7.5 The operating principle of the variable-capacitance transducer.

5.7.6 What is the optimal frequency for the study testing transducer?

5.7.7 What is the optimum transducer for the study?

5.7.8 What is the sensitivity of variable-capacitance transducers?

5.7.9 Errors of variable-capacitance transducers.

6 LABORATORY WORK # 6

STUDY OF POTENTIOMETRIC TRANSDUSER

The duration of the laboratory session is 2 hours.

6.1 The purpose of the work

The purpose of work is to define construction of potentiometer transducer, to study their static and dynamic characteristics, to determine static sensitivity.

6.2 General notes

The resistance transducers are used for control of line and angular displacement, pressure, temperatures et cetera. Their principle of operation is based on active electric resistance variation under influence of measuring signal. For their power supply the sources of direct or alternating current can be used. The voltage or current will be output parameters depending on input ones (as a potentiometer or variable-resistance). In the resistance transducers of position its mobile element is mechanically related to the operating mechanism (OM). The change of operating mechanism position made the variation of the transducer resistance.

Wired potentiometric sensors, which are designed for more accurate measurements, are widely used in automatic systems. As a rule, their designs are a frame made of hetinax, textolite or ceramics, on which a thin wire is wound in one layer, turn to turn, on the cleaned surface of which a current-collecting contact (slider) slide (Figure 6.1). The frame is made of insulating material or metal covered with a layer of insulation. In terms of shape, frames are flat, cylindrical and ring. The winding is made with high-resistance wire made of manganin, constantan, nichrome, etc. The diameter of the winding wire, depending on the required accuracy, is 0.03 for low-class sensors. The winding wire is covered with enamel or a layer of oxides.

These sensors belong to the common displacement (displacement) sensors, which can measure both linear displacement (with translational displacement) and rotation angle (with rotation). They belong to the parametric type sensors and convert mechanical movements into changes in the active resistance of the electric circuit, and are also called resistive

sensors with variable resistance. The wire is wound on a flat, cylindrical ring frame made of dielectric (textolyth, electric ebonite, getinax, etc.), and for particularly accurate sensors - on a metal frame sprayed with insulating oxides (for example, Al_2O_3), which dissipate heat well. Sliders are usually made of palladium alloys with iridium, silver, or cobalt ($\text{Pd} + \text{Ir}$, $\text{Pd} + \text{Ag}$, $\text{Pd} + \text{Ag} + \text{Co}$) and others. In order to ensure contact when moving from one turn to another, the slider must touch the previous turn and the next at the same time (Figure 6.1).

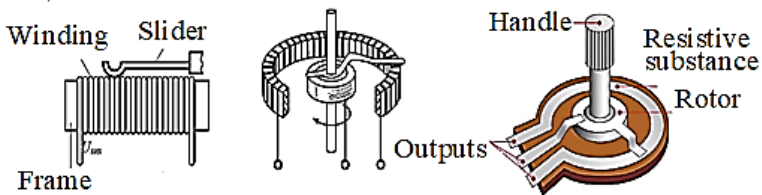


Figure 6.1 - The principle of di ĩ potentiometric sensor

The potentiometer transducer is presented by variable resistance, the contact of which displaced according to mechanical stress. This transducer can be used to transform angular or linear mechanical travel to corresponding variable resistance, voltage or current.

One-cycle potentiometer transducer (Figure 6.2) is presented by wire resistance which put in the circuit of voltage.

Static characteristic of potentiometer can be as linear as non-linear function $U_x = f(x)$.

The connection of the potentiometer slider and the source of input signal have kinetic character. In this case coordinate X is the variable displacement which characterizes the position of slider according to beginning of potentiometer winding.

One-cycle transducer allows testing only one sign displacement. The execution of leading-out wire from average point is need for design of transducer, which react upon a sign of internal winding displacement.

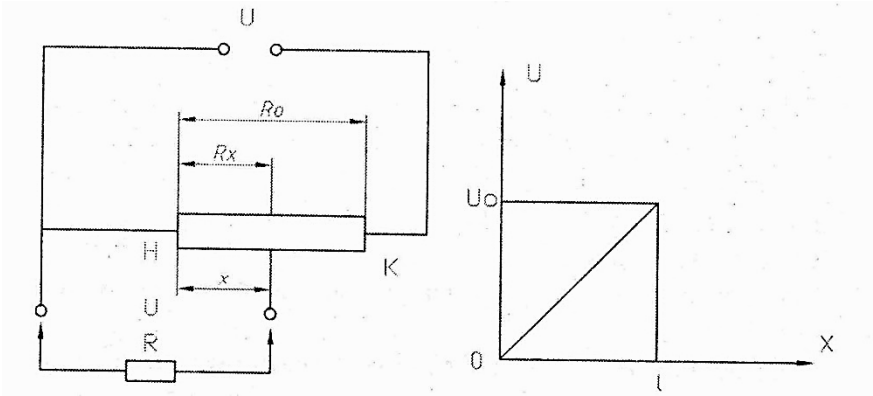


Figure 6.2 – The one-cycle potentiometer transducer and their static characteristic

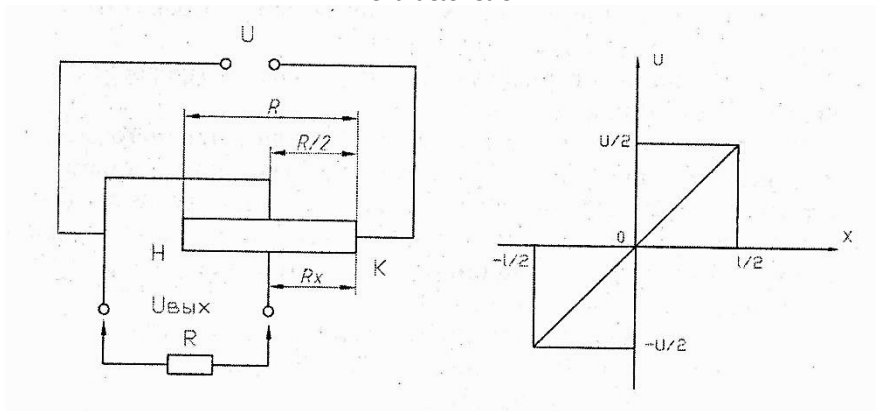


Figure 6.3 – The two-cycle potentiometer transducer and their static characteristic

Aluminum case is a good heat conductor. It allows increasing density of the current in the winding, so consequently the sensitive of potentiometer transducer.

6.3 Steps of work execution

1) Before laboratory work execution student have to study methodical instructions and repeat chapter devoted to potentiometer transducer.

2) Prepare Tables 6.1 and 6.2.

3) Connect a circuit on the Figure 6.4.

4) With the help of regulator T using voltmeter metering values set voltage equaled to 10 volts.

5) For testing step-type potentiometer transducer set the slider of potentiometer R1 to the leftmost state.

6) Set the switch S12 to the leftmost state.

7) Rotating axis of potentiometer R2, write down metering values of voltmeter to the table 6.2 every 45° .

8) Set the switch S12 to the state “2”. Do the same that is in the seventh item.

9) Set the switch S12 to the state “3”. Do the same that is in the seventh item.

10) Set the switch S12 to the state “4”. Do the same that is in the seventh item.

11) For testing of two-step potentiometer transducer with artificial center point, set the slider of potentiometer R to the middle state. Do the same that is in the previous item. Begin to write down all metering values in the leftmost state of potentiometer R slider. Pay attention to the U_{out} sign. All metering values write down to the Table 6.2.

12) Using testing data plot static characteristics $U=f(j)$, on one graph. Make conclusion.

13) Calculate sensitivity of the potentiometer transducer.

14) Using testing data plot a static characteristic of off-load operating of single step-type potentiometer transducer with artificial center point (when $R_H=\infty$).

15) Using testing data plot static characteristic of potentiometer transducers when:

16) $R_H=R_o$, $\alpha=1$, $R_o=2,2k\Omega$,

17) $R_H=10R_o$, $\alpha=0,1$,

18) $R_H=15R_o$, $\alpha=5$, where R_o is a total resistance of potentiometer.

19) Define static characteristics of transducers when R_H is different.

Make an analysis of obtained results and make a conclusion.

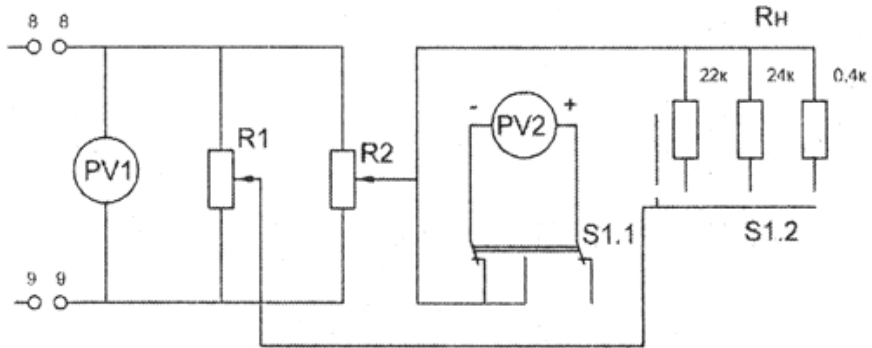


Figure 6.4 – Principal circuit of potentiometer transducer testing

Table 6.1 – Testing data

Rotation angle of R1 axis J, degrees	0	45	90	135	180	225	270	300
$U_{out, 1}, V$								
$U_{out, 2}, V$								
$U_{out, 3}, V$								
$U_{out, 4}, V$								

6.4 Safety method instruction

All commutation of the circuit execute at switch QF turned off.
Clearly follow safety methods instruction and internal order rules.

Table 6.2 – Testing data

Rotation angle of R2 axis J, degrees	0	45	90	135	180	225	270	300
$U_{\text{out}, 1}, \text{V}$								
$U_{\text{out}, 2}, \text{V}$								
$U_{\text{out}, 3}, \text{V}$								
$U_{\text{out}, 4}, \text{V}$								

6.5 Control questions

6.4.1 Construction design and using of potentiometer transducer.

6.4.2 Main characteristics of potentiometer transducer.

6.4.3 Advantages and disadvantages of potentiometer transducer.

6.4.4 What is insensitive zone?

6.4.5 What is static characteristic of a transducer?

6.4.6 How does load influence on the static characteristics of potentiometer transducer?

6.4.7 What does static sensitivity of transducer depend on?

6.4.8 In what cases is it necessary to use functional potentiometer transducer?

7 LABORATORY WORK # 7

STUDY OF VARIABLE-INDUCTION PICK-UP

The duration of the laboratory session is 2 hours.

7.1 The purpose of the work

Purpose of work: to study with action principle and structural features of variable-induction pickups, find out parameters of transducer by experiments and to give their analysis.

7.2 General notes

A transducer (sensor) is the first element of measuring circuit, as a rule, analog device, giving out information about the parameters of the system and its processes. It is the basic source of an electric signal (change of the electric circuit state due to its shorting and breaking, change any electric parameters – R, L, C - or generations EMF – electromotive force). Then this signal is processed, transformed to the kind, which is comfortable for a transmission by the communication lines and its further transformation and use.

An electric transducer (sensor) is a device which responds, as a rule, physical variable (speed, acceleration, pressure, temperature, humidity, illumination (intensity), composition and percentage of impurity, frequency of vibrations (oscillation), color etc).

7.3 Steps of work execution

Before execution of laboratory work a student must independently learn the actual methodical directions, repeat the section of course about variable-induction pickups and prepare Tables 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7 and 7.8, and assemble a circuit (Figure 7.1).

It is need to support voltage of voice generator constant on a value at any measuring.

7.3.1 Measuring of inductances $L_1(x)$ and $L_2(x)$ at different fixed positions of core is executed by a voltammeter method. In order to measure a current and voltage in a coil the switch S 3.1 must be switched to position «2», and switch S 3.2 in position «0». Write down registration of PV1 and

PA into the Table 7.1. For measuring of current and voltage at the same value X in a coil switch S 3.2 must be put in «2» position, and S 3.1 in «0». Write down registration of PV1 and PA to Table 7.1.

For measuring of current and voltage at the same value X in 2 coil the switch S 3.2 must be put in position «2» and S 3.1 in «0». Write down registration of PV1 and PA to Table 7.1.

In the experimental variable-induction pickup the measuring borders $0 < x < 3$ mm is divided on the row of areas (marks on brass part of core).

Proposing consistently 5-6 values X , execute measuring of each X , on 1 and 2 coils. As a result of measuring to calculate $L1(x)$ and $L2(x)$ use the given formulas in appendix.

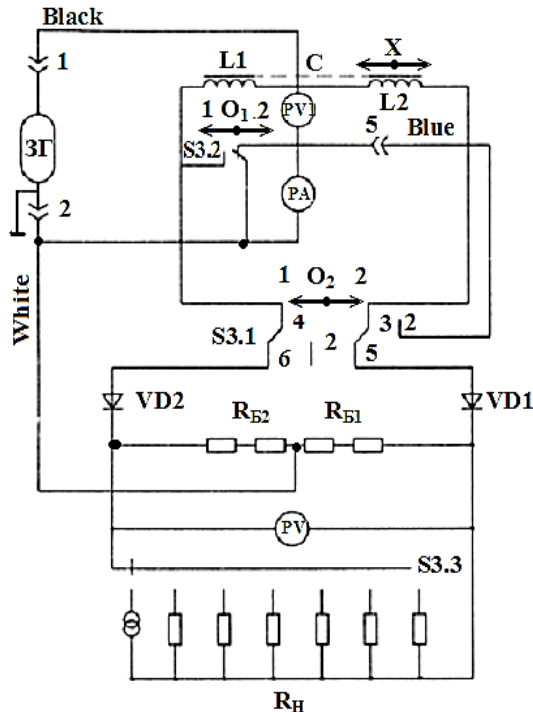


Figure 7.1 – Testing circuit of variable-induction pick-up

Table 7.1 – Results of experiments

Value	1	2	3	4	5	6
X , mm						

Z1, Ohm						
U ₁ , V						
I ₁ , A						
Z2, Ohm						
U ₂ , V						
I ₂ , A						
L 1, H						
L2, H						

7.3.2 Calculate characteristic U₂ (x) by given in appendix formulas. Value s of R_H and R₀ are given in the end of text.

Execute calculation at frequency f=400 Hertz. Write down the results of calculation to the Table 7.2.

Execute calculation for the values of R_H. By the data from Table 7.2 plot graphs U(x) at R=const in one axis.

Table 7.2 – The results of calculation

Value		1	2	3	4	5	6
R _H 1	X, mm						
	Kz						
	U ₂ , V						
R _H 2	X, mm						
	Kz						
	U ₂ , V						

7.3.3 During the experiment a switch must be turned up in "1"- "1". Carry out test at $f=4000\text{Hz}$. Write down results of calculation to Table 7.3.

By the data of table 7.3 plot the graph $U(x)$ at $R=\text{var}$ in one axis with the graph by Table 7.2 and to compare them with the calculated ones.

Table 7.3 – Results of testing

Value		1	2	3	4	5	6
$R_H = 1 =$	X, mm						
	U_2, V						
$R_H = 2 =$	X, mm						
	U_2, V						

7.3.4 Using the graphs, which was got at execution of 2 and 3 and the formulas resulted in addition, define dependence between coefficients of sensitiveness of transducer from R_H to $\kappa(R_H)$. Plot in the same axes of coordinates graphics $R(R_H)$. Compare two curves and to give the analysis. Write down the results of calculation to the Table 7.4.

Values ΔX and ΔU_2 take from the rectilinear areas of characteristics

Table 7.4 – Results of experiments

#	R, Ohm	$\Delta X, \text{mm}$		$\Delta U_2, \text{V}$		$K, \text{V/mm}$	
		calcula- tion	experi- ment	calcula- tion	experi- ment	calcula- -tion	experi- ment

7.3.5 Arbitrarily choose value $R=\text{const}$. Consistently set frequencies $f=(10^3, 2 \cdot 10^3, 3 \cdot 10^3, 4 \cdot 10^3, 5 \cdot 10^3) \text{Hz}$. At every fixed frequency by the help of the formulas resulted in appendix 1 calculate $U_2(X)$. Then execute the experimental measuring of $U_2(X)$ at those frequencies. Write down the results of calculations and experiments to the Table 7.5.

Table 7.5 – Results of experiments and calculations

#	$f=10^3 \text{ Hz}$			$f=2 \cdot 10^3 \text{ Hz}$			$f=3 \cdot 10^3 \text{ Гц}$			$f=4 \cdot 10^3 \text{ Hz}$		
	X, mm	Kz	U ₂ , V	X, mm	Kz	U ₂ , V	X, mm	Kz	U ₂ , V	X, mm	Kz	U ₂ , V
		calc	test		calc	test		calc	test		calc	test

All graphs (with the data that was got experimentally and calculated) must be built in one co-ordinate. Plot the graphs of $U(x)$ got experimentally and upon calculations in one axis.

7.3.6 Using the got graphs in 5 and the formulas of appendix, calculate $K(f)$ for experimental and calculated data. Write down the results of calculations to the Table 7.6.

Table 7.6 – Calculated data

№	$f, \text{ Hz}$	$\Delta X, \text{ mm}$		$\Delta U_2, \text{ V}$		$Kz, \text{ V/m}$	
		calc	test	calc	test	calc	test

Plot two graphs $K(f)$ calculated and experimental. Build both graphs in one coordinate axes. Give the analyses of both graphs.

7.3.7 Calculate errors of sensor that depended from frequency of voltage and R_H with the help of data of experiments 3, 4, 5 and formulas given in appendix. Write down the results into the Tables 7.7 and 7.8.

Table 7.7 – Calculated data

№	R_H			
	$\Delta U_2, \text{ V}$	$U_{2\text{calc}}, \text{ V}$	$\Delta U, \%$	$R_H, \text{ Ohm}$

Table 7.8 – Calculated data

№	f			
	$\Delta U_2, V$	U_{2calc}, V	$\Delta U, \%$	R_H, Ohm

Build the graphs $\Delta U\% (f)$ and $\Delta U (R_H)$. Give the analyses of the characteristics.

7.4 Appendix

$$Z = \sqrt{R^2 + (\omega L)^2} \cong \omega L, \omega = 2\pi f;$$

For every coil $Z=U/I$. $L \cong \frac{1}{\omega} \sqrt{Z^2 - R^2} \cong \frac{Z}{\omega};$

$$U^2 = 0.45 \lambda U_1 Kz.$$

Value of coefficient λ depends on shadow of neighboring metal parts and other factors ($\lambda = 0.2 \dots 1$). In our laboratory work take $\lambda = 0.4 \dots 0.6$.

$$Kz = \frac{L_2 - L_1}{\omega \frac{L_1 \cdot L_2}{R\acute{a}} + L1 + L2 + \frac{R\acute{a}}{\omega} + 2\omega L1 \cdot L2 + R\acute{a}(L1 + L2)}.$$

$$K = \frac{\Delta U_2}{\Delta X}; \Delta U\% = \frac{U_{2calc} - U_{2test}}{U_{2calc}} \cdot 100\%.$$

Values of R_H and R_G :

$$R_{H1} = 0.3 \text{ kOhm}$$

$$R_{H2} = 0.56 \text{ kOhm}$$

$$R_{H3} = 1.0 \text{ kOhm}$$

$$R_{H4} = 2.0 \text{ kOhm}$$

$$R_{H5} = 3.3 \text{ kOhm}$$

$$R_{H6} = 6.2 \text{ kOhm}$$

$$R_{G1} = 1.5 \text{ kOhm}$$

$$R_{G2} = 1.5 \text{ kOhm}$$

7.5 Safety method instruction

All switching in the circuit execute along with cutout QF turned on.
Clearly follow safety methods instruction and internal order rules.

7.6 Control questions

7.6.1 Give definition of transducer and variable-induction pickup.

7.6.2 What constructions are self-generating and modulating transducers?

7.6.3 What principle of variable-induction pickup operation?

7.6.4 Advantages and disadvantages of high-frequency variable-induction pickups.

7.6.5 What operation principle of testing circuit of variable-induction pickup?

7.6.6 What relationships of all graphs?

7.6.7 Make conclusions about properties and errors of transducers and variable-induction pickup?

8 LABORATORY WORK # 8

STUDY OF REED RELAY MODEL

The duration of the laboratory session is 2 hours.

8.1 The purpose of the work

The purpose of work is to study the concept of operation, construction design by the symmetrical neutral reed relay model, controlled by current winding; to plot tractive and opposition characteristics of this relay; to determine a rotation angle of relay operation, reset ratio of current reed relay, controlled by field of current bus; to study the construction of industrial reed relays КЭМ-2, КЭМ-3, etc.

8.2 General notes

The subjects of study are:

- relay P1 (figure 8.3) is a model of symmetrical neutral reed relay with a closed contacts controlled by a current coil;
- relay P2 is a current reed relay, controlled by field of current bus;
- testing representative specimen is the relay ПИГ-011011Y3;
- the production prototypes.

Model view is shown on the figure 8.1. P1 is model of the symmetric neutral closed reed relay controlled by a current winding (figure of winding includes "big" turns (1), their number is equal to 1000, and "small" turns (2), their number is equal to 4; then the total number of turns creating operation MMF is equal to 4000, or (1000×4)). P2 is a current reed relay, controlled by field of current bus; HL is a signal lamp, signaling about closing of P1 and P2 relay; П is a switch; 1 is a testing representative specimen is the relay ПИГ-011011Y3; 2 are the production prototypes КЭМ-2, КЭМ-3.

The principal electric circuit, mounted on the stand panel is shown on figure 8.3. The relay winding (turn) P1 is connected to the source of DC voltage up to 200 V. The turn (bus) of relay P2 (contains 600 turns) is connected to the source of DC voltage of 16 V.

Measuring instruments PA1, PA2, PVI, PV2 are connected to the line terminals according to the figure. 8.3.

Lamp HL is connected via transformer 1220 / 6 and into the

commutation circuit KC1 of relay P1 or KC2 of relay P2 by switch II. The transformer secondary winding is earthed.

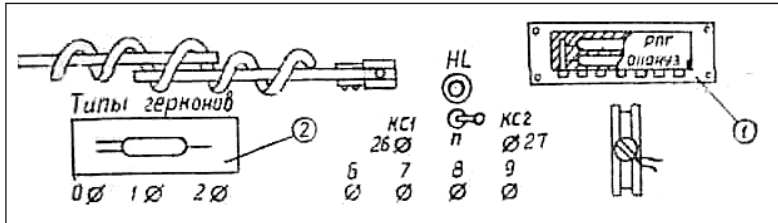


Figure 8.1 – Sketch of the panel with the reed relay

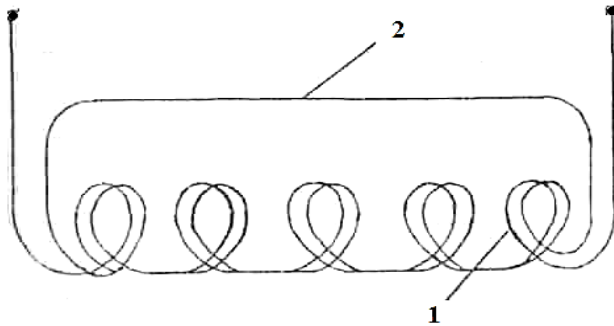


Figure 8.2 – Sketch of the winding

To analyze the serviceability of the relay it needs to plot opposition and tractive characteristics, which are being plotted in the same coordinates.

To plot the opposition characteristics such formula is used [1]:

$$F_{mch} = C \cdot y,$$

where F_{mch} – is a force opposing to closing of contact details (mechanical force of elasticity), N;

y – is the initial gap between the contact details, m;

C – is a stiffness of contact details, N / m.

where l_{KC} – is the length of contact details, m;
 a – is the length of the overlapping contact details at the operating gap, m;
 E – is an elasticity modulus of material contact details, N / m.

To plotting the tractive characteristics the formula of Maxwell is used [4]

$$F_{\text{ЭМ}} = \frac{\Phi^2}{2\mu_0 S}; \Phi = \frac{I \cdot \mu_0 S W}{l_{\text{KC}}}. \quad (8.2)$$

Then
$$F_{\text{ЭМ}} = \frac{\mu_0^2 S^2 W^2}{2\mu_0 S l_{\text{KC}}} \cdot I^2.$$

where $S=b \cdot h$ – is a section of contact, m^2 , see fig. 8.4;

$S'=a \cdot b$ – is an area of overlap, m^2 , see fig. 8.4;

W – is a number of turns of the control coil;

μ_0 – is a magnetic constant, H / m ;

μ – is an absolute magnetic permeability, H / m .

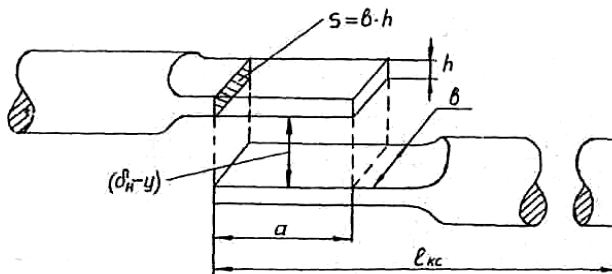


Figure 8.4 – Sketch of location contact

8.3 Steps of work execution

8.3.1 To study the design of relay models P1 and P2, ПИГ-011011Y3 and industrial reed relays КЭМ-2, КЭМ-3, etc.

8.3.2 To calculate the stiffness by formula (8.1) where E to take from the table 8.1, and the value of l_{KC} get on the relay model P1. Then, setting the values of y from 0 to ... (air gap of a contact details), to plot opposite characterization reed relay $F_{\text{MX}}=f(y)$.

8.3.3 Determine experimentally and plot tractive characteristics of relay P1 $F_{\text{MX}}=f(X)$, the dependence of current $I=f(X)$ and power $P=f(X)$.

8.3.4 Determine experimentally and plot the current dependence current $I=f(\alpha)$ and power $P=f(\alpha)$ for the relay P2.

8.3.5 Determine the value of the angle at the border of P2 relay operation.

8.3.6 According to the results of experiments and calculations to do conclusions.

8.4 Methodical guide

8.4.1 Circuits for the experiments with the relays P1 or P2 to connect according to the fig. 8.3.

8.4.2 To except sealing of the relay P1 it is need to put foil on contact details. To measure the thickness of aluminum foil by micrometers, this would be consistent with δ_0 .

8.4.3 Regulator of the laboratory stands to the left position (position 0). A switch Π set to KC1 and the KC2, depending on the testing relays P1 and P2.

8.4.4 In the study of the P1 relay switch Π set to KC1, and gradually increasing the voltage regulator T, to fix the values of voltmeter RV1 and ammeter PA1 (desktop devices) at different values of a and y. Start to measure it is necessary at $a_{\max}$ & $y_{\min}$. The values of a, y, b, h, l_{KC} are measured by scale rule.

Different values of y are determined by set regulators on the contact details, which can also experimentally determine the maximum air gap of contact details δ_H , that is starting of reed relay operation. Data are recorded into the table. 8.1. At first setting y values and then changing values of a (3 values) to study the relay P1.

8.4.5 Build dependencies $F=f(y)$, $F_{\partial M}=f(y)$, $I=f(y)$, $P=f(y)$, and the $F_{MX}=f(y)$ & $F_{\partial M}=f(y)$ to plot on the one coordinate space.

8.4.6 At the study of P2 relay to set Π switch to position KC2 and gradually change the current by the regulator T, taking of ammeter evidence PA2 and voltmeter PV2 during the operation and release of the relay P2. Do these measurements at different values of the angle α , between the longitudinal axis of reed relay and direction of current in the bus.

Table 8.1 – The data of measurements and calculations

№	Testing values								Calculated values				Constant values
	y	U	I	a	b	h	l _{KC}	δ ₀	Φ	F _{MX}	F _{ЭМ}	P	
1													C=4000N/m ² E=1.36·10 ⁻¹¹
2													
3													
1													μ ₀ =4π·10 ⁻⁷ H/m
2													
3													
1													μ=65000 for testing alloy
2													
3													

8.4.7 Determine the limits of the angle of operation α_{np} . Write down a result in the table 8.2.

8.4.8 Determine the $(IW)_{op}$, $(IW)_{res}$, $K_{res} = \frac{IW_{op}}{IW_{res}}$, plot graphs $(IW)_{op}=f(\alpha)$, $I_{op}=f(\alpha)$, $K_{res}=f(\alpha)$, $P_{op}=f(\alpha)$ dependences.

8.5 The contents of the report

8.5.1 Tasks.

8.5.2 The circuit of the testing reed relays.

8.5.3 The constructive difference between the industry reed relays from each other on the stand.

8.5.4 Tables and graphs of the calculated and experimental data.

8.5.5 Conclusions based on each function and on report as a whole.

Table 8.2 – The data of measurements and calculations

№	Testing values					Calculated values				Constant value
	α	I_{op}	I_{res}	U_{op}	U_{res}	IW_{op}	IW_{res}	K_{res}	P_{op}	
1 2 3	90^0									W=600
Aver										
1 2 3	75^0									
Aver										
1 2 3	60^0									
Aver										
1 2 3	Angle on the border of operation									
Aver										

8.5 Control questions

8.5.1 Give the definition of stable equilibrium point.

8.5.2 What cause of vibration (chatter) of switching contacts at reed relay operation?

8.5.3 Give principal difference between operation process of reed relay and standard armature relay.

8.5.4 What reed relay operation function MMF of coil position of air gap?

8.5.5 How does function I_{op} depend on angle of the longitudinal axis rotation of reed relay and direction of current in the bus?

8.5.6 What kind of MMF resetting function and K_{res} of reed relay depend on contact overlap values?

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