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IMPROVEMENT OF THE METHODOLOGY OF LABORATORY PRACTICES FOR TRAINING ELECTRICAL ENGINEERING EXPERTS

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The curricula of higher education institutions that train specialists in the field of electrical power engineering, envisage mastering a certain list of competences, achieving program results, which allow to solve specialized practical problems, the solution of which is unlikely without the use of theoretical basis and methods of physical, natural, social and economic sciences. The modern engineer must possess the certain set of knowledge and skills that allow him or her to theoretically anticipate, substantiate and determine particular tasks, situations, problems. The topical issue of modern higher education is the preparation of a competitive in the labor market specialist, who is able to combine the theoretical knowledge gained with practical skills, who can design a detailed model of the sequences of required actions and tasks, as well as to justify the choice of a particular equipment and toolsets. However, the excessive amount of data that influences the modern young individual in one way or another does not allow him/her to concentrate his/her work in the necessary direction in order to determine priorities, including choosing and studying a particular course. Recently, a young person is not always aware of the

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need to perform the types of tasks envisaged in the curriculum, thus, treating the overall educational process lightheadedly without real-life industrial conditions proper simulation and analysis. Therefore, one of the main tasks of the teacher is to assist the student in combining theory with practice, in order to give impetus to independent actions, stimulating them to actively perform cognitive and research activities.

The article deals with the problem of close combination of laboratory work with practical investigation in order to increase their joint efficiency. The combination of theory and practice that occurs in the laboratory during the laboratory procedures involves the activation of students' cognitive activity, the provision of specific nature of the learned material at lectures and independent work, facilitating detailed and deeper assimilation of educational information. At the same time, the compliance of laboratories with the requirements of technical aesthetics and ergonomics, methodological substantiation of laboratory and practical classes will contribute to the education of students in the sphere of culture of work, which will also positively affect the quality of students' educational and cognitive activity, as well as their practical training. Our research offers a technique for improving laboratory work by introducing experimental verification of the results obtained during independent work.

Key words: *theoretical training, self-study, students' cognitive activity, practical work, laboratory work, theoretical foundations of electrical power engineering, workbook, experimental assessment.*

УДОСКОНАЛЕННЯ МЕТОДИКИ ПРОВЕДЕННЯ ЛАБОРАТОРНО-ПРАКТИЧНИХ ЗАНЯТЬ ПРИ ПІДГОТОВЦІ ФАХІВЦІВ З ЕЛЕКТРИЧНОЇ ІНЖЕНЕРІЇ

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Навчальні програми закладів вищої освіти, що ведуть підготовку фахівців у галузі електроенергетики, передбачають опанування певним переліком компетентностей, досягнення програмних результатів, що дають можливість вирішувати спеціалізовані практичні задачі, вирішення яких малоймовірно без застосування теорій і методів фізико-технічних, природничих та суспільно-економіко наук. Сучасний інженер повинен володіти тим переліком знань і умінь, що дозволяють теоретично передбачати, обґрунтовувати та визначати ті чи інші виробничі завдання, ситуації, проблеми. Актуальною проблемою сучасної вищої освіти підготовка фахівця, конкурентоспроможного на ринку праці, який здатний поєднати отримані теоретичні знання з практичними навичками, здатний моделювати процес та обґрунтовувати вибір того чи іншого обладнання. Проте надмірна кількість потоків інформації, які тим чи іншим чином впливають на сучасну молоду людину, не дозволяють їй концентрувати свою роботу в необхідному напрямі з метою визначення для себе пріоритетних завдань, у тому числі під час вивчення того чи іншого курсу. Останнім часом молода людина не завжди усвідомлює необхідність виконання видів завдань, передбачених навчальними програмами, підходить до вивчення поверхнево, не проектуючи матеріал, що вивчається, на реальні виробничі умови. Тому одним з основних завдань педагога є надання допомоги студенту у поєднанні теорії з практикою, надання поштовху до самостійних дій, які викликають інтерес до досліджень, активізують пізнавальну діяльність.

В даній роботі розглядається проблема тісного поєднання лабораторних робіт з практичними для збільшення їх сумісної ефективності. Поєднання теорії і практики, яке відбувається в лабораторії під час виконання лабораторних робіт, передбачає активізацію пізнавальної діяльності студентів, надання конкретного характеру вивченому матеріалу на лекціях та при самостійній роботі, сприяння детальному і більш глибокому засвоєнню навчальної інформації. При цьому відповідність лабораторій вимогам технічної естетики та ергономіки, методичне обґрунтування лабораторно-практичних занять сприятиме вихованню у студентів культури праці, позитивно впливатиме на якість навчально-пізнавальної діяльності студентів і їх практичну підготовку. В роботі запропоновано методику удосконалення лабораторних занять *шляхом впровадження експериментальної перевірки власних результатів, отриманих під час самостійної роботи.*

Ключові слова: *теоретична підготовка, самостійна підготовка, пізнавальна активність студента, практична робота, лабораторне заняття, самостійна підготовка, теоретичні основи електротехніки, робочий зошит, експериментальна перевірка.*

Introduction of the issue. The growth of the total amount of scientific knowledge and integration of science, on the one hand, and increasing specialization of knowledge on the other, demand that fundamental training of students must be of a high level and intensity, but at the same time it must be carried out according to the needs of society to the multilateral development of personality combined with the maximum development of his/her individual abilities and inclinations. The educational programmes of many higher education institutions, which are used in the process of training of electrical engineering specialists, provide graduates with the ability to solve specialized issues and practical problems not only in the specific discipline or field of knowledge, but in electrical engineering and electromechanics in general. The rapid development of industrial production, its scientific substantiation, support and improvement are closely dependent on the development of the education. Successful implementation of modern production processes is associated with the generalized combined qualities of a specialist, as well as with the level of professional suitability and competences acquired through education. This encourages the application of theories and methods of engineering sciences in practice and is characterized by the complexity and uncertainty of the conditions.

As for the realization of the potential of a personality, it can be achieved, if the education system enables every young individual on a broad general- and narrow specific field-based foundation to receive appropriate multiprofile qualification with the particular specialization, which means mastering a profession at the highest possible level. One of the main tasks in the training of professionals is a fundamental improvement in the quality of education.

The list of competences that a modern engineer should possess, first of all, includes the ability to theoretically predict, substantiate and determine topical production tasks, situations, problems and issues. The combination of theoretical knowledge with practical skills, the ability to model the process and competently justify the choice of appropriate equipment makes a graduate of higher technical education competitive in the modern labor market. Thus, the organization of the educational process according to the model "lecture (theory) – practical work – laboratory work – preliminary or final assessment" is substantiated enough in the study of not only electrical engineering disciplines, but natural sciences as well.

Laboratory classes belong to the category of organizational forms of the educational process, where, first of all, the issues of integration of knowledge, intellectual, as well as practical skills and abilities form such important professional and personal qualities of the student as independence, activity, ability to think freely and analytically, mastering new ways and methods of problem-solving, extrapolating and applying them to new situations, etc.

They are conducted through the students' self-completion of quite specific subject tasks using equipment adapted to the conditions of the educational process, which reflects or models production-based situations. One of the important advantages of laboratory work, in comparison with other types of classroom activities, is the integration of theoretical knowledge with practical skills of the student in a single research-like process [5]. Quality laboratory work requires the students' creative initiative, autonomy in decision-making, deep knowledge and understanding of educational material.

Practical work, as a method of learning, is a way of discovering and enhancing the skills of calculating and justifying choice of corresponding equipment, devices and production-critical procedures; thus, by didactic nature, practical work is close to laboratory work [10: 3]. Laboratory work and practical activities unite and complement each other, moreover, in some cases, the term "laboratory and practical work" (for example, in physics, electrical engineering, electronics, metrology, etc.) is used.

Increase in the efficiency of the laboratory and practical activities, including proper organization of educational and methodological work requires educator's deep knowledge of form and structure of each separate type of lessons, creating appropriate environment for the development and improvement of students' skills and abilities in engineering disciplines. Currently, thorough research and practical activities in the field of development and approbation of different systems of pedagogical monitoring and assessment of laboratory-practical lessons are being conducted [6; 7; 8].

Object of research: laboratory and practical activity of the vocational training educator of higher educational institutions.

Subject of research: laboratory-practical works as the tool of mastering knowledge, skills and abilities by the students.

Aim of research is to identify theoretical and practical aspects of improving the organization of laboratory-practical works as a form of assessment of vocational knowledge of students of tech specialties in higher educational institutions.

Current state of the issue. Performing the task of improving the quality of education requires the implementation of a range of measures aimed at enhancing different components of training process, moreover, previous experience and analysis of technical disciplines' structure has detected the ineffectiveness of conventional lesson-based material presentation. In order to increase the efficiency of the educational process, it is necessary to determine the ways to improve the system of education, which helps to increase the level of students' knowledge assimilation and skills formation. For this purpose, a system consisting of the following levels is becoming particularly popular: motivational basis (interest) → active mental activity → individual perception of educational material → imagination → ability to create → development of thinking and emotional perception → synthesis of knowledge → conscious learning → abilities and skills → creativity → productive activity. The implementation of this system uses: didactic principles aimed at ensuring the effective acquisition of knowledge; development of analytical abilities and skills. The development of analytical thinking involves a holistic perception of the studied objects and phenomena, the separation of the constituent elements of internal and external interconnections.

A prerequisite for the implementation of such a system is the choice of forms of organization of students' educational activities. In the international educational and pedagogical practice, such means of an objective assessment of the level of mastery of the integral, general and professional competences of the applicant of engineering specialties becomes more widely used.

However, there is a number of disadvantages in the organization and conduct of laboratory classes in pre-higher and higher education institutions: the equipment used does not always meet current requirements; the sequence of laboratory work on topics for each student does not always correspond to the structural and logical scheme of the discipline – the topics of laboratory work do not always coincide with the material learned during lectures and seminars; the level of independent preparation of students for laboratory work is inadequate; control of readiness of each student at admission to laboratory work is not deep enough; students do not always have sufficient skills in analyzing the phenomena under study and the ability to make conclusions from the results of experiments; students spend most of their time not achieving the main goal of the work, but performing intermediate activities; the individual preparation of the student is not always taken into account; when evaluating the results of laboratory work, the focus is often on the structure and design of the report, without properly assessing obtained practical skills and abilities. As for the forms of organization of laboratory work, they can be divided into frontal, group, individual.

The *frontal form* of conducting laboratory work is the most widespread, and is characterized by forming relatively small groups of students (3-4 individuals) accomplishing the same tasks, while performing similar work simultaneously. Laboratory work of this type is carried out in accordance to special programmes and instructions. Conducting work in such a way does not require considerable effort on the part of the teacher regarding its organization, however, it requires a sufficient number of corresponding equipments. The frontal form of the organization of the laboratory work gives the opportunity to save the teacher's time for the development of content and selection of distributing material, as well as it helps to evaluate the feedback and perform assessment.

The major disadvantage of frontal laboratory work form is the low cognitive autonomy of students in the process of tasks completing. Besides, performing the laboratory work simultaneously implies coping techniques and methods of execution of certain tasks without understanding the essence of the phenomenon investigated, uncontrollable exchange of experimental data between the group members, which leads to formation of noncreative mechanical patterns of behavior.

The *group form* of organizing the laboratory work implicates the distribution of different tasks and equipment, which are preliminary selected for each group of students within the same topic. It has a number of advantages: first of all, the possibility of taking into account the individual characteristics of students, including: the level of their academic achievements, interests, ability to provide assistance or being assisted by groupmates, assessment, self- and mutual assessment. In addition, this work form allows the students to use the equipment more efficiently. Moreover, each group performs a particularly selected task, which reduces to the minimum the possibility to cheat or share the experimental data between the representatives of different work groups.

The *cyclical form* of laboratory activities involves the division of all laboratory activities, provided by the programme of the course, into several cycles, which correspond to its certain sections. Each laboratory work is performed according to the schedule, which allows to perform simultaneously different types of lab work of a certain cycle.

The major disadvantage of this kind of activity is their discrepancy with the theoretical material presentation and distribution, which results in incomplete or incorrect understanding of the origin and/or essence of the investigated phenomena, thus, reducing cognitive activity of the students.

Individual form provides for each participant to perform a certain laboratory work on a special schedule, while all the students simultaneously work on different topics. It should be noted that such type of activity requires a special organization, individual guidance and control over the work of students from the side of a teacher. However, it allows to take into account the individual characteristics of each student during the course of work

According to our point of view, the use of individual laboratory classes is appropriate at the beginning of the first year of study, when students learn the methodology of experimental work in the laboratory. The use of such courses in senior courses should be based on the specific interests and inclinations of particular students, as well as providing the variability of tasks.

Therefore, it can be noted that the individual form of laboratory work meets the current trends of the education system, in particular, it implements a personality-oriented approach, promotes individualization and differentiation of learning. The essence of individual form of organizing laboratory work lies in designing individual tasks, choosing and differentiating didactic material, setting goals and objectives of the corresponding kinds of activities, implying variability of the algorithm of its compliance, taking into consideration the tempo of the educational process in accordance to the needs and capabilities of particular students, the level of formation of their skills, abilities and their theoretical readiness.

The *differentiated form* of organization of laboratory work requires more teacher's effort and time, in addition, the process of obtaining the feedback after the accomplishment of individual tasks and their assessment is significantly complicated. Regardless of the specifics of the forms of organization of laboratory work in the process of its implementation, such methods as analysis, synthesis, comparative analysis, diagnosis, conclusions making are predominantly used.

In the process of performing laboratory work, students obtain theoretical and practical knowledge, independently make "discoveries", polish individual executive and self-experimental skills, perform multiple research activities, as well as learn how to plan step-by-step sequences of actions, predicting preliminary and final results, evaluate probabilities, etc.

It is also important for the teacher to ensure that the laboratory work is well-organized and precisely conducted (for example, to clarify the subject, goals and tasks; to instruct students on the performance of the work; to remind the rules of conduct and safety).

The laboratory class should be held with the number of students that does not exceed half of the academic group. In some case (requirements for safety of life, limited number of workplaces, etc.) it is allowed to conduct laboratory classes with even smaller number of students.

Assessing the forms of organization of laboratory work, we note that each of them has its own peculiarities, in particular, the disadvantage of the frontal form is the low cognitive independence of students during its implementation [2]. Performing laboratory work by all students of the subgroup simultaneously leads to copying techniques and effective means of performance while solving problems without a deep understanding of the essence of the phenomena under study, thus, the efficiency of mastering the respective competences greatly decreases.

The disadvantage of the cyclical form of organization of laboratory work is its dynamic nature that outpaces the study programme material, which leads to incorrect and inaccurate understanding of phenomena or processes, and, as a consequence, reduces the students' cognitive activity [2].

One of the main tasks of improving the educational process is designing new methods of organizing its forms, including laboratory classes. The following ways can be distinguished in this direction: improvement of the material and technical base of laboratories; improvement (complication) of previously performed laboratory works; modernization of the laboratory structure, methods of measurements and calculations, etc.; increase of activity and independence of students; use of computer technology. Thus, according to our point of view, one of the major ways to enhance the organization of the laboratory practicum in higher and pre-higher educational institutions is to strengthen individual work with students, namely in conducting laboratory classes, controlling and assessing them.

The individual form of conducting laboratory work provides for each student to perform certain sequence of tasks on a special schedule, which is possible only with sufficiently strong material base, and requires a lot of teacher's time, who is responsible for conducting the monitoring and assessment of the corresponding students' activities. However, it allows to find individual approach to each student and to take into account his/her personal abilities and skills.

Therefore, it can be emphasized that the individual form of laboratory work corresponds to the current tendencies of the development of the education system, in particular, it implements a personality-oriented approach, promotes the individualization and differentiation of learning.

Laboratory classes are considered the most conservative according to its organization and methodology. This is strongly connected with the functions they perform, the content of the work and the specificity of the learning process to acquire the relevant practical skills and abilities. Ya. Ya. Boliubash [3] distinguishes the following stages in the structure of modern laboratory classes:

– preliminary control of students' readiness for specific laboratory work;
– performing specific tasks in accordance with the topics offered;
– failing individual report;
– assessment of students' work by the teacher/supervisor.

Thus, students are presented with a list of individual tasks:

- to understand and properly formulate the aim of the experiment;
- to present its course independently and clearly;
- to select the necessary equipment items;
- to carry out the experiment, including the observations stage;
- to record the results of the experiment.

After that, the student, based on his/her own theoretical knowledge or using auxiliary specialized literature, substantiates the obtained results. The teacher acts as a consultant, providing the student with the necessary and appropriate methodological assistance.

Results and discussion. It is important to create appropriate psychological environment, such conditions for students at the laboratory-practical classes that would stimulate them to work creatively, so the teaching and support staff must be highly-qualified and undergo corresponding pedagogical training [9].

In this situation, classes should be organized in such a way that each student (academically: strong, medium, weak), corresponding to the professional level, felt the need to improve the quality of his/her training. Thus, the teacher, according to the needs and interests of the student, should provide methodical assistance, creating a set of individual tasks, taking into account his/her level of. Individualizing the tasks of laboratory and practical work, it is necessary to preserve the integrity of the system of theoretical and practical training, the connections between them, to consider them as a whole, when each lesson is a topically-completed link of the educational process.

Due to specific psychological and age-based peculiarities, students can much more easily and effectively percept and assimilate the visual and interactive forms of educational material in comparison with abstract textual assets [4]. It is known that according to the theory of associative memorizing, data that is obtained via multiple channels, including text, video, graphics and sound is being deeply stored in memory and can be access for significantly longer period of time, thus, making the interactive forms and means of education increasingly popular.

As laboratory work may be limited to a range of competences, it is appropriate to combine it with such means of assessment as oral questioning or testing. Moreover, such a combination may sufficiently encompass the examination of knowledge and the ability of the student to minimize the time costs, and also exclude any written sphere difficulties. It should be noted that alongside with capable individuals with good theoretical basis and ability to successfully use it while dealing with real-life activities, there are mediocre students with insufficient level of training, but with a well-developed intuition that increases the probability of obtaining academic achievement, similar to those of the better trained individuals. In our case, interactive forms and means of presenting educational material are of higher effectiveness due to close interconnection of laboratory and practical classes.

As long as laboratory work may limit the range of competences developed, it is appropriate to combine it with such lessons as individual practical work. Thus, the student mandatory receives a list of vital theoretical knowledge and practical skills on a particular topic, making the successful completion of the tasks given without them impossible. After conducting calculations required, the student should check them experimentally by performing laboratory work. The quality of performance of the calculation part, the level of assimilation of theoretical material is assessed during oral questioning or testing, which saves the time and effort of the teacher.

This hypothesis was tested on the example of the discipline "Theoretical Foundations of Electrical Engineering", designed for students, who receive a Bachelor's degree in the specialty 141 "Power engineering, electrical engineering and electromechanics". The aim of laboratory-practical classes of the corresponding discipline is to teach students the methods of calculating electromagnetic processes and corresponding energy transformations, mastering the basic concepts and laws related to the practical use of electrical and magnetic phenomena, mastering methods of analysis of electric circuits (DC and AC).

The most important condition for the effectiveness of training in carrying out laboratory and practical work is the obligatory independent cognitive work of the student, therefore, students are offered workbooks, which contain guidelines and essential theory on the topic. Workbook contains structural directions for the following tasks:

– independent homework;

– experimental tasks for classwork;

– practical tasks to substantiate laboratory work.

The workbook contains systematized and clearly outlined theoretical and methodical material that covers practical and methodological issues of the discipline "Theoretical Foundations of Electrical Engineering". The structure of all laboratory works, their content and visual illustration of theoretical material by the schemes of measurement of electrical and magnetic quantities are methodologically justified, which makes the instructions of the workbook convenient for independent study of the material by students of full-time and part-time (distance) forms of study [5].

As an example, lets review a fragment of a workbook from the discipline "Theoretical Foundations of Electrical Engineering". For the branched electric circuit (fig. 1) it is known: electromotive force (EMF) of electric current sources and resistance of the resistor (table 1).

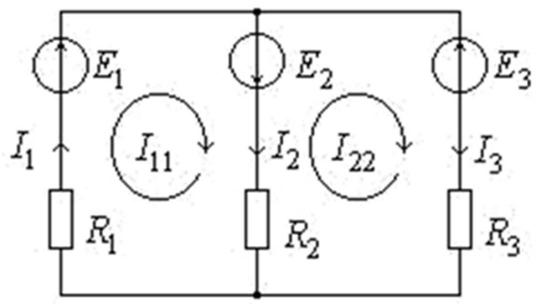


Fig. 1. Schematic diagram of electric principle for laboratory and practical work

The task is to determine the currents in the design (fig. 1) wiring diagram by:

1) Kirchhoff's Laws (Kirchhoffsches Gesetz / KL);

2) the method of contour currents (MCC);

3) the two-node method (TNM).

Next stage is the assessment of experimental data obtained.

Table 1

Source data for the calculation work

Variant	**R ,Ом**			**E, V**			**Методи виконання**	
	R1	**R2**	**R3**	**E1**	**E2**	**E3**	**Full-time**	**Part-time**
1	130	120	110	10	15	12	KL, TNM	TNM, KL
2	82	120	110	11	12	15	MCC, KL	MCC, TNM
3	130	68	110	13	17	10	MCC, TNM	TNM, KL
30	130	68	110	16	13	18	KL, TNM	TNM, MCC

Note:

The internal supports of the sources are equal to e.s. – 0 Ohms

KL – Kirchhoff's Law

MCC– the method of contour currents

TNM – the two-node method

Figure 3 shows a diagram of typical electrical laboratory installation for checking the correctness of home practical work in the form of an example of the calculation of currents of a branched electric circuit (fig. 1) (direct current / with two nodes). The calculation method is given in the workbook. The general view of the laboratory installation is shown on figure 2.

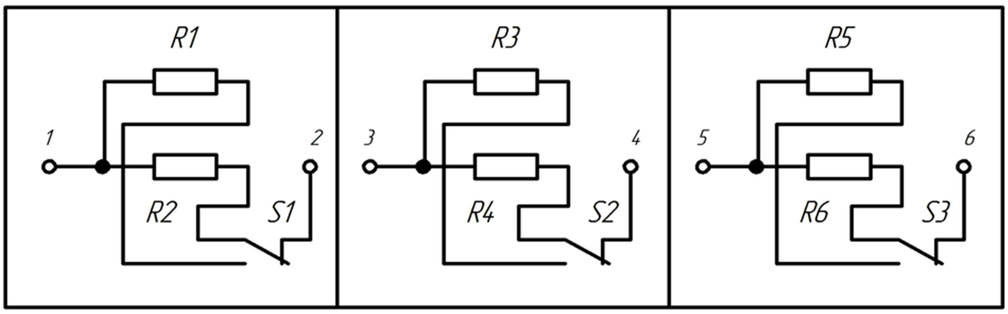
Fig. 2. General view of the laboratory installation.

The laboratory installation consists of two parts:

Part one – power supply with three identical adjustable integral stabilizers (5… 25 V) with power load of 1 A each. Integral stabilizers are protected against overload. Fig. 1 indicates that they correspond to E1… E3. The choice of integral stabilizers due to their proximity to the ideal voltage sources for internal resistance;

Part two – power load resistors (R1...R3), which consist of resistors of variable power load (fig. 3).

a



b

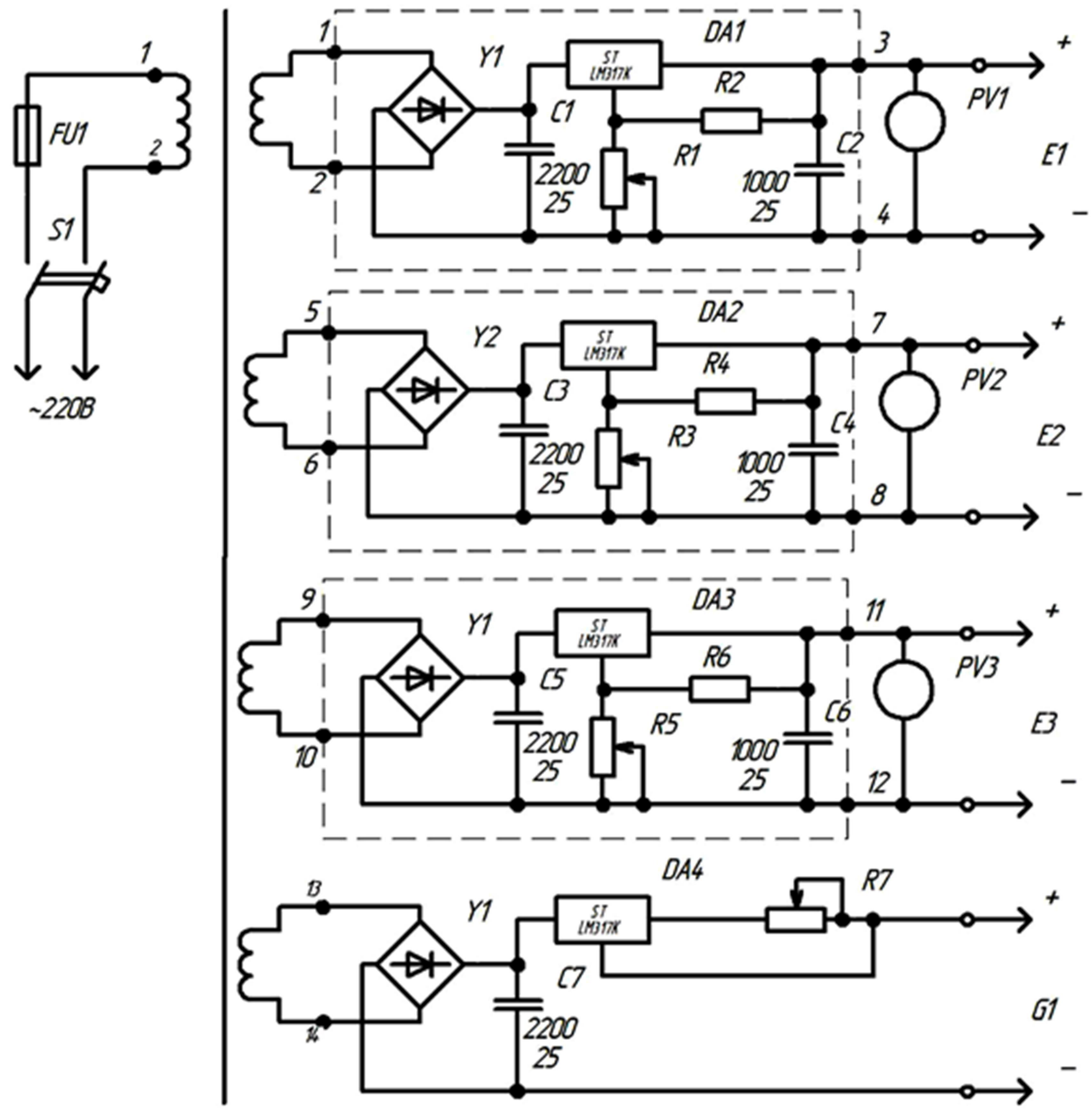


Fig. 3. Schematic of typical electrical installation for laboratory work. a – power supply unit (PSU); b – resistors matrix

Resistors' power load is given in table 1. The number of resistors in combination is 9. The number of combinations of EMF values is quite large. The magnitude of the currents in the respective circles is determined by Ohm's law:

$$I_i = \frac{U_R}{R_i},$$

where U_R – *is voltage drop on resistor*.

The voltage drop is determined by a digital combination device located on the power supply unit. This (indirect) measurement method allows to expand the possibility of obtaining information on the application of two laws - the second Kirchhoff's law and Ohm's law. Resistors R1, R3, R5 modulate corresponding voltage of power supply units E1...E3. To complicate the practical task, a current generator (current source) G1 is provided. This laboratory equipment acts as a "lie detector" in checking the quality of previously performed calculations. The preliminary calculation of currents is performed within the framework of practical or independent work of students.

Conclusions and research perspectives. Described method of organization of laboratory-practical work encourages the student to perform corresponding types of activity independently, thus, requiring only obligatory preliminary comprehension of theoretical material, which is needed to master programme(s) of a particular discipline.

The experience of using the combined form of practical-laboratory classes convincingly indicates that the developed system gives the opportunity to form the ability of students to analyze the sets of experimental tasks, as well as to conduct experimental activities freely and independently, while being engaged in decision-making and taking responsibility for relevance of obtained results of the experiment. Further research perspectives imply developing a reliable methodological ways and means of student's self-assessment, experimental data generalizations and assimilation, while maintaining their considerable freedom and independence.

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