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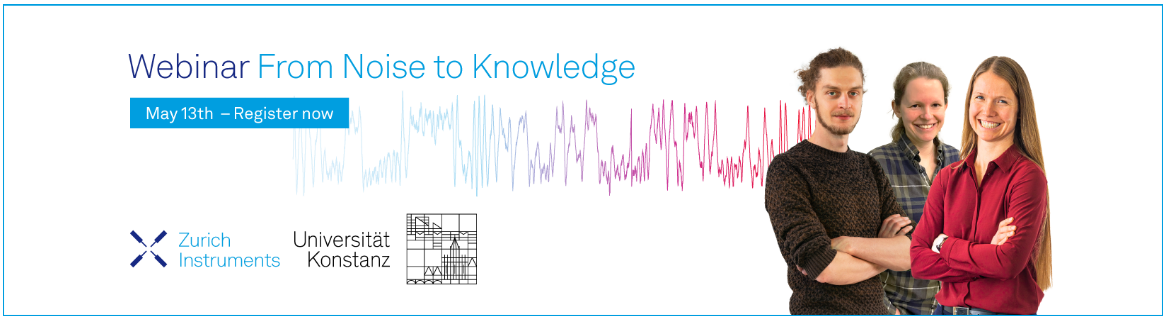

Inter-Subject Relations of Physics and Energy Disciplines, as a Didactic Condition for Increasing the Quality of Students' Knowledge

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Abstract. This article presents a systematic approach to examining the content of academic disciplines that requires careful study of the connections between individual disciplines and between the various issues presented within each discipline. The consistency of the presentation of material between different courses and between different topics within each course is one of the most important indicators of the quality of educational material. Inconsistency and contradiction in the presentation of related issues have a negative academic impact, leading to a decline in the prestige of the educational process and confusion in the scientific worldview of students. We can discuss a systematic approach in two slightly different aspects: "in the big" and "in the small". In the first case, we should talk about the connection between different courses, their consistency and continuity, the commonality of scientific language in related courses, the place of courses in the curricula of various specialties, and, of course, the content of each course, its significance for a specialist in this profile and the disciplines based on this course. In the second case, the systematic approach is reflected in the methodological unity of presenting various issues within each course.

INTRODUCTION

The development of energy industries at the present stage requires the training of highly qualified engineering and scientific personnel with the system integration of education, science and production programs. The process of development of educational systems at the stage of a large-scale experiment to update the content and structure of higher education in Uzbekistan [1,2,3,4] is characterized by increased requirements for the level of culture and professional qualifications of specialists, an increase in the general level of education, the development of a system of continuing education, the most connected links of which are higher education of students and the system of continuing pedagogical education of teachers working in higher educational institutions. Under these conditions, higher education in the energy sector also plays a special role, which is the result of integrating a system of fundamental knowledge of electrical engineering, electronics and physics.

Our research on the teaching of electrical engineering, combining the study of discipline issues in the field of energy, shows the possibility of significantly increasing the effectiveness of the educational process in improving the technological training of students. In accordance with the purpose of our article, the following research objectives were set:

To analyze the state of the problem of implementing interdisciplinary connections in the educational process in electrical engineering and subjects in the field of energy, physics at a higher technical university, to identify ways to improve the quality of subject knowledge for future bachelors.

To reveal the meaningful connections of electrical engineering and disciplines in the field of energy, ways to implement these connections in the educational process.

To substantiate the study of the basics of modern electric power engineering in the course of electrical engineering, as its integral component, ensuring an increase in the efficiency of technological training of future bachelors.

The following research methods were used to solve the tasks set:

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- theoretical: - analysis of curricula and programs, educational and methodological literature on specialties in order to study the completeness of reflection in them of issues related to the implementation of interdisciplinary relations;

- empirical: - observation of the educational process during attendance and conducting training sessions, conversations with teachers, conducting and analyzing control papers, questioning students;

- a pedagogical experiment in all its forms (ascertaining, trial, training and control) to verify the effectiveness of the proposed methodology for teaching technical disciplines focused on the implementation of interdisciplinary connections considered in training courses;

Modern electric power engineering disciplines represent a variety of differentiated and integrated sciences that are in close interaction, thanks to which electric power science penetrates deeper into the knowledge of the surrounding world. The methodological basis for the interaction and interrelation of scientific knowledge, as well as interdisciplinary connections of higher educational disciplines in the field of energy, is also the material unity of the surrounding world. Obviously, it is necessary to change the priorities in the educational process of higher educational institutions (universities), to move from strictly subject-oriented learning, the main purpose of which is to transfer the content of this subject area to learning focused on the formation and development of students' skills, with the help of which students learning is carried out on the basis of broad interdisciplinary interaction and generalization of knowledge of related subjects.

In this regard, the problem of a meaningful and procedural revision of scientific education in the field of energy becomes urgent, in which interdisciplinary connections should be maximally implemented, which will significantly facilitate the study of related disciplines. Such a discipline as “Electrical Engineering” occupies a special place in the preparation of future bachelors of power engineers, because theoretically and practically it is inextricably linked with many electrical engineering disciplines such as electric machines, electrical measurements, high voltage engineering, physics, mathematics and others. Electrical engineering, as a general technical discipline, has an integral basis in structure and content. Studying it will be effective if we use didactic conditions for the implementation of interdisciplinary connections, primarily with physics, which is the scientific basis of electrical engineering.

EXPERIMENTAL RESEARCH

Electrical engineering as a science and academic discipline originated as a result of the application of physical phenomena in the field of technological processes of transformative human activity. The structural components of knowledge - facts, concepts, laws, theories, fundamental ideas, methods of science - are common to both physics and electrical engineering. Therefore, the formation of fundamental scientific and technical concepts, theoretical and experimental research methods, methods of educational cognition in the course of electrical engineering is advisable to carry out in the context of the implementation of interdisciplinary connections with physics. However, the physics course does not always give a clear understanding of such basic physical quantities as EMF, voltage and potential difference, tension, polarization and displacement in an electric field; induction, magnetization and tension in a magnetic field. These three triples of concepts, of which the first is scalar and the last two are vector, should be formulated so that their use in any electrical engineering tasks does not contradict the basic concepts laid down in the physics course.

It is necessary that the definitions of the main vectors be, and that the displacement vectors in the electric field and the magnetic field strength be determined on the basis of two other vectors, the physical interpretation of which was given earlier for electric and magnetic fields. Only then is it possible to introduce the concepts of dielectric and magnetic permeability. However, this is not always done in physics courses [5]. As an example, we can point out the serious remarks that arise in connection with the introduction of the concept of the magnetic field intensity vector $\vec{H}$. In physics courses, usually, when identifying the physical meaning of this vector, either an infinite solenoid with an infinite round rod made of a homogeneous ferromagnet or an annular continuous magnetic circuit is considered.

It follows from these examples that the magnetic field strength is determined only by external currents, and the additional component of magnetic induction due to a magnetized substance is proportional to the magnetization at a given point. For the idealized examples under consideration, this is true. However, for any practical task where the magnetic circuit is open, all these “physical” representations lose their meaning. It is necessary to consider the problem of an inhomogeneous magnetic circuit containing an air gap. Only in this case it is possible to give a general definition of the magnetic field strength necessary for a correct analytical description of a magnetic circuit with a magnetizing coil or with a permanent magnet. In all cases, the magnetic field strength,

$$\vec{H} = \frac{\vec{B}}{\mu_0} - \vec{M} \tag{1}$$

here $\vec{B}$ and $\vec{M}$ — magnetic induction and magnetization vectors with a clear physical interpretation. Only with such a determination of the magnetic field strength is it possible to solve many problems of calculating magnetic circuits, which are posed by the practice of studying specific electromagnetic devices. Speaking about the coordination of various courses, it is worth mentioning the issues of feedback theory, which are of great importance in the courses of theoretical foundations of electrical engineering (IE), automatic control, industrial electronics and electrical machines. The need for a unified presentation of these issues has been highlighted in some publications [6, 7].

As an example of the use of various scientific languages in different electrical engineering courses, one can consider the interpretation of the term “cascade” given in courses on electrical machines and industrial electronics. In the first case, it is a set of machines acting on each other, and in the second case, it is one element of an amplifying circuit. It seems to us that we should limit ourselves only to the first meaning of this word and not apply it when talking about one element of the scheme.

When considering the connections between different courses, it can be very useful to formalize these connections and give them a convenient mathematical description. In the graph of connections between different courses presented in Fig. 1, far from all connections are indicated, since a more complete consideration of curricula as a large system leads to a cumbersome and poorly visual graph. In this case, it is more convenient to describe the links between different courses in the form of matrices [8, 9] and, analyzing them, adjust both the content of the courses and their place in the curriculum of each specialty. The commonality of concepts, laws, theories and research methods of related disciplines creates conditions for continuity in the educational process, contributes to the deepening and improvement of the quality of knowledge based on the implementation of interdisciplinary connections.

In the context of the accumulation of scientific knowledge and the complexity of the content of academic subjects, the leading place in the learning process is given to improving didactic and methodological approaches to teaching in the implementation of interdisciplinary connections. One of the important directions in the formation of holistic and systemic knowledge, in particular, in electrical engineering, is the teaching of this subject in terms of interdisciplinary communication with physics and disciplines in the field of energy, which is the basis of electrical engineering.

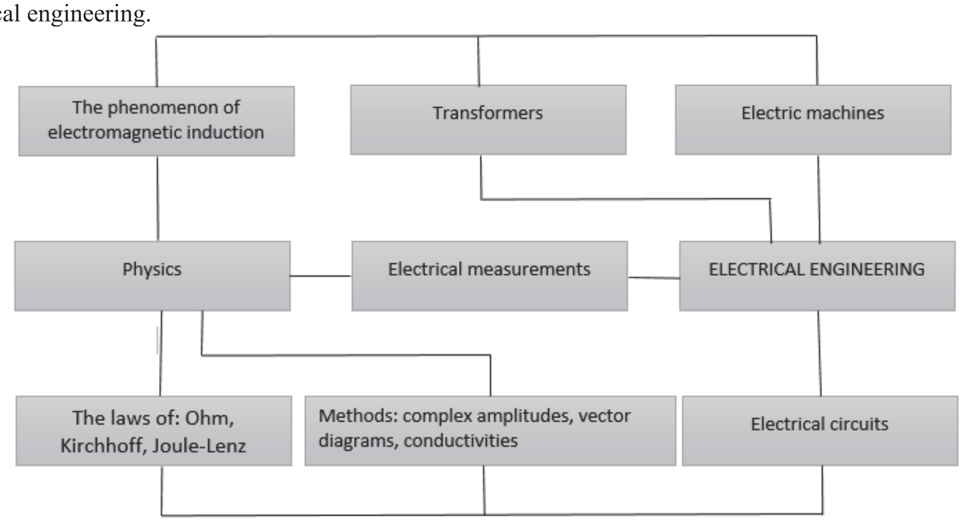

FIGURE 1. Structural and substantial connections of physics and electrical engineering

As previously noted, the electric power industry, the content of which has an integrative character, contributes to the development of professional creativity, improves the quality of students' knowledge and ensures the connection of learning with students' production activities. The methodology of teaching electrical engineering provides ways to carry out interdisciplinary communication with physics and subjects in the field of energy in various types of classroom classes, as well as in the organization of technical creativity, the performance of research works of students and theses. The whole system of methods is aimed at developing the student’s cognitive abilities: assimilation of not only the results of scientific knowledge, but also the process of obtaining these results. For the successful implementation of interdisciplinary connections in the learning process, it is necessary to know the specifics of the methodology for the formation of theoretical knowledge, cognitive and practical skills common to physics and electrical engineering.

Interdisciplinary connections in teaching students general technical disciplines are established based on the analysis of the existing methodology of studying the subject. In this case, electrical engineering and subjects in the field of energy as an academic discipline are considered and studied as science, technology and technology in their unity:

1. Electrical engineering and subjects in the field of energy as the science of the practical use of electrical and magnetic phenomena or (second definition) as a science of production, transmission, distribution, conversion and use of electrical energy, it is based on scientific principles and laws of physics.

2. Electrical engineering and subjects in the field of energy as a technique designed for the conversion, transmission and application of electrical energy, represents technical objects created on the basis of scientific knowledge from the field of physics, electronics, mathematics, etc.

3. Electrical engineering and subjects in the field of energy are represented by electrical technologies of industry, agriculture and others. At the same time, for each technological purpose of a particular type of energy, either the conversion of forms of energy or the “direct” effect of electric current, electric or magnetic fields is used. The formation of scientific knowledge, fundamental scientific, technical and technological concepts, the study of theoretical and experimental research methods in the course of electrical engineering should be carried out when implementing interdisciplinary connections in methodological, theoretical and practical aspects.

RESEARCH RESULTS

The use of interdisciplinary connections as a didactic condition for increasing the effectiveness of a lecture depends on the specifics of the content and methodological approaches to the study of individual topics. The lectures provide a cross-cutting relationship between physics, mathematics, electrical engineering and disciplines in the field of energy and this serves as the foundation for the formation of scientific knowledge of students in electrical engineering. From this point of view, we will analyze the educational significance of the lecture and the methodological features of studying individual topics of the electrical engineering course. In order to use all the advantages of a lecture as a form of learning and minimize its disadvantages, it is necessary to correctly determine the place of this form of study in the educational process, considering it as a stage in the formation of knowledge and skills. Obviously, it is necessary to change the priorities in the educational process, to move from the old subject-oriented learning, the main purpose of which is to transfer the content of this subject area, to learning focused on the formation and development of students' skills, with the help of which the educational cognition of students is carried out on the basis of broad interdisciplinary interaction and generalization of knowledge of related subjects. And this stage is very important, since the lecture should introduce the student to a new topic, arouse interest in it, show the purpose of studying this material, give orientation for preparing for laboratory and practical classes and for independent work on literary sources.

The main task of each lecture is to show the essence of the topic, analyze its main provisions in the context of the interrelation of knowledge, motivation of students to independent work. To help students work independently, the lecturer should specify more specifically on this topic the scope, methodological features of studying the material, taking into account interdisciplinary connections, practical application, etc. In the process of studying electrical engineering and subjects in the field of energy, students develop technical thinking, in the structure of which the following logical operations can be distinguished: analysis, synthesis, comparison, generalization, establishment of cause-and-effect relationships in the study of methods of obtaining, transmitting and using electrical energy. An electrical device functions as a single whole due to not only mechanical, but also electromagnetic coupling of individual parts, which are stable and provide the appearance of a number of new properties not inherent in disconnected parts. The study of electrical devices requires a high level of analysis and generalization necessary for the assimilation of complex processes occurring in them.

In interdisciplinary relations, it is worth mentioning the issues of feedback theory, which are of great importance in the courses of TUE, automatic control, industrial electronics and electric machines. The need for a unified presentation of these issues has been highlighted in some publications [10, 11]. When considering the connections between different courses, it can be very useful to formalize these connections and give them a convenient mathematical description.

When considering the task of interdisciplinary connections, it is necessary to focus on the links between the content of the course and the profile of the specialist studying this course. With limited study time at the university, it is very important to exclude issues of little importance for this specialty from the course and focus on issues necessary for specialists of this profile. The solution to this important issue is not always sufficiently justified and is sometimes subjective. This can be especially difficult in the electrical engineering training of non-electrical specialists, who receive the basics of such education from the electrical engineering and electronics (EiE) course, the scope of the program of which depends on the profile of the specialty. The general part of this program contains information from the courses of TOE, industrial electronics, electrical machines, electrical measurements and electrical wiring, the presentation of which in a single course requires methodological unity, which is not always provided by a systematic approach to the formation of all these courses of interdisciplinary connections. The disadvantages of coordination between courses are manifested in methodological inconsistency within the EiE course. Let’s focus on some examples of methodological inconsistencies within different courses.

The following example applies to a physics course or the physical fundamentals of electrical engineering. It is expressed in the absence of methodological unity in the description of the potential and vortex components in the electric fields of electrodynamic systems. For an electromagnetic field in a system of stationary bodies, consideration of Maxwell's equations in the absence of extraneous forces of nonelectromagnetic origin leads to the following expression for the electric field strength;

$$\vec{E} = \vec{E}^{pot} + \vec{E}^{v}\ , \tag{2}$$

here $\vec{E}^{pot}$ — the potential component of the electric field strength;

$$\vec{E}^{pot} = -grad\ \varphi \tag{3}$$

$$\vec{E}^{v} = -\frac{d\vec{A}}{dt}, \tag{4}$$

$\vec{E}^{v}$ — the vortex component of the field caused by a changing magnetic field;

$$\varphi = \frac{1}{4\pi\varepsilon_0}\int_v \frac{\rho}{r}\ dv, \tag{5}$$

Here is the potential of a point defined by charges with density, ρ,

a vector potential expressed in terms of currents with density $\vec{J}$,

$$\vec{A} = \frac{\mu_0}{4\pi}\int_v \frac{\vec{J}}{r}\ dv, \tag{6}$$

In this case, stress is understood as the curvilinear integral of $\vec{E}^{pot}$ on the considered section of the path from *a* to *b* (Fig. 2):

$$u_{ab} = \int_a^b \vec{E}^{pot}\ \overrightarrow{dl}\ , \tag{7}$$

and under the induced EMF — there is an integral on the d — c section.

$$e_{dc} = \int_d^c \vec{E}^{v}\ \overrightarrow{dl}\ , \tag{8}$$

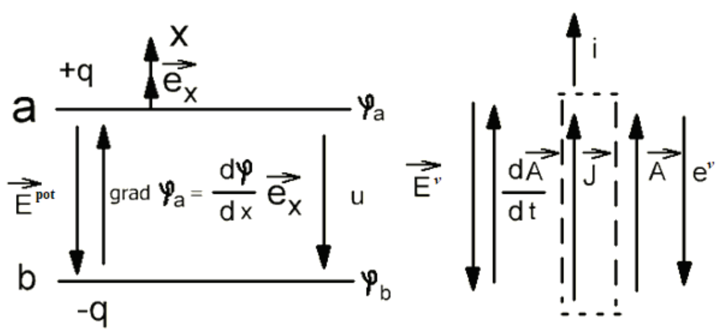

FIGURE 2. Unit vector axis notation $\vec{e}_x$.

In the electrical circuit, the positive direction chosen for u-voltage and e- EMF is understood to be the positive direction of the integration path from a to b, or from d to c, coinciding with the direction of the vector (dl)⃗, which for (7) and (8) may be the opposite.

Choosing a positive direction is similar to choosing a direction on a geographical map. You can limit yourself to two coordinate axes pointing east and north. Then, instead of the southern direction, say “minus north”, and for the west, “minus east”. At the same time, there will be no confusion when moving around the geographical map. However, isn't it convenient and easier to deal with the four directions; north, south, east and west? It is the same in electrical engineering. In the law of electromagnetic induction, instead of the direction “to the left”, “minus to the right” is usually taken and this entails some inconveniences. Of course, this does not bring mistakes, all calculations turn out to be fair, however, in a number of tasks this disadvantage leads to inconsistency, and sometimes to minor errors, not to mention confusion in students' ideas.

The above examples of inconsistency in the presentation of individual topics within the physics course and within the course of electric machines. These examples are given in order to draw attention to the consideration of logical connections between different topics and to the need to harmonize the methods of presenting related issues. Similar problems arise when considering four-pole and feedback circuits in electrical engineering, electrical machines and electronics, self-oscillation and many other issues [12]. There is an urgent need to consider educational program complexes not as “a series whose members are simply applied to each other”, but as statements of problems that should “necessarily flow from one another”. The issues of a systematic approach to teaching electrical engineering disciplines are also considered in [13,14].

CONCLUSIONS

Considering the above, the following conclusions can be made:

- interdisciplinary connections of electrical engineering and disciplines in the field of energy, physics as a didactic condition for improving the quality of knowledge of future bachelors ensure consistency and coordination of work programs in electrical engineering and disciplines in the field of energy, physics;
- eliminate duplication of educational material;
- ensure the unity of interpretation of general concepts, laws and theories;
- contribute to the formation of generalized approaches among students to the assimilation of the main structural elements of knowledge (scientific facts, concepts, laws, theories) and the implementation of these approaches in their independent cognitive activity.
- the formation of complex interdisciplinary knowledge among future bachelors is facilitated by their completion of a diploma project of an experimental and research nature based on the manufacture of a prototype of a technical object on an urgent topic.
- the implementation of a didactic system of interdisciplinary connections plays an important role in improving the methodology of students' educational activities, it allows changing the priority from mastering ready-made knowledge to independent active cognitive activity, taking into account the need to form a modern integral style of thinking.
- the implementation of interdisciplinary connections in the educational process creates important conditions for the activation of students' cognitive activity, which contribute to arming them with general methods of cognition and the formation of generalized approaches for students to assimilate the basic structural elements of knowledge. One of the aspects of the organization of integral cognitive activity of students in teaching electrical engineering is the independent establishment of connections and relationships of the studied technical objects, the definition of the scientific foundations of their functioning and the correlation of the structure of technical objects with technological operations that are carried out in connection with production assignments.

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