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The Assessment of the Educational Value of the Utilization of Training Modules at the Laboratory of Power Electronics

***Abstract**. The paper raises the issue of how important the educational process of students in the field of power electronics is. It presents the advantages and disadvantages of laboratory classes performed with the utilization of training modules, which have schematic symbols of the particular elements drawn on the front housing. In addition, the paper includes the students' impressions of such laboratory stands. The presented opinions have been gathered based on conducted surveys.*

***Streszczenie.** W artykule podjęto kwestię, jak ważny jest proces kształcenia studentów w zakresie energoelektroniki. Przedstawiono wady i zalety zajęć laboratoryjnych realizowanych z wykorzystaniem modułów szkoleniowych, które posiadają schematyczne symbole poszczególnych elementów narysowane na przedniej części obudowy. Ponadto w pracy zamieszczono wrażenia studentów dotyczące pracy na takich stanowisk laboratoryjnych. Prezentowane opinie zostały zebrane na podstawie przeprowadzonych ankiet. (**Ocena wartości dydaktycznej wykorzystania modułów szkoleniowych w Laboratorium Energoelektroniki**).*

Keywords: education, power electronics laboratory, training modules, survey.
Słowa kluczowe: edukacja, laboratorium energoelektroniki, moduły szkoleniowe, ankieta.

Introduction

Power electronics has become a significantly relevant topic on account of the variety of applications such as electric cars, variable-speed motor drives, smart grids, and others [1,2,3]. The constant development of this branch has shown how much engineering is meaningful for the advancement of technology and that it can make a contribution to the enhancement of human life [4].

The industry has been revolutionized by advances in semiconductors technology combined with the need for systems which are compact, fast and of high efficiency. This, in turn, has resulted in high demand for power electronics engineers [2].

The power electronics engineering profession is fed the power electronics engineering education [5]. This statement remains true worldwide regardless of time. Studying such discipline constitutes a demanding process that includes not only lectures but also practical classes like laboratory work [6]. Laboratory classes in power electronics are especially important as they can help students comprehend theoretical content and ideas. Not only do they show how to apply acquired knowledge in practice, but also make students familiar with the devices, equipment and measuring apparatus they will work with in the future.

It is said that teaching is as much art as it is science [7]. On account of the fact that power electronics is still evolving, which results in the appearance of innovative solutions, the teaching process should combine basic methods with new ones. New manners of teaching might be useful to make technical subjects more attractive to students and make the teaching process itself easier and more effective [8]. However, there is no universal way to teach since there are several factors that matter. Among them there are teachers' personal preferences, the number of students in the group attending the classes as well as the availability of diverse teaching support equipment. Basic laboratory stands mostly consist of personal computers with simulation software allowing conducting simulation tests of developed control systems. Simulations play a significant role in the learning process [9] since they allow students to design control systems for various purposes and simultaneously provide feedback on the operation of these developed systems.

Nevertheless, this type of laboratory classes does not provide knowledge of the structure of individual systems, e.g. transducers, converters, or knowledge of the correct connections between the individual elements of the system, which includes the measuring equipment. However, such opportunities give laboratory stands equipped with power electronics training modules.

This paper presents the concept of power electronics laboratory stands with the utilization of training modules. This work shows the advantages and disadvantages of such a solution. Furthermore, the paper focuses on the students' opinions on this type of learning [10]. It is an important issue so long as it is students who are the main users of these devices and should reap the benefits from working on educational equipment.

The opinions have been gathered on the basis of answers given in the surveys. They were conducted during the last classes, at the end of the whole semester of laboratory classes with the exploitation of the training modules.

Power electronics laboratory

The curriculum for engineers studying electrical engineering at the Faculty of Electrical Engineering of the Gdynia Maritime University is developed in accordance with the guidelines of the Minister of Science and Higher Education and the requirements of Standards of Training, Certification, and Watchkeeping (STCW). Education at the Faculty of Electrical Engineering prepares engineers to work on land and at sea, therefore, it is important to meet the requirements of both mentioned institutions. Preparing engineers to work both ashore and offshore require extensive competencies, but also involves additional requirements in the field of teaching power electronics, which is now ubiquitous both in industry and on the ships. Nowadays, renewable energy sources are used in a trouble-free manner and electric ships or even 100% autonomous vessels will appear. All this means that the education of a modern electrical engineer must also take into account the requirements of the future.

Education in the field of power electronics is therefore an important element of the development of every electrical engineer. The program should involve all the requirements, which is why education in the field of power electronics at the Faculty of Electrical Engineering includes acquiring knowledge in various forms over several semesters. In addition to the traditional form of lectures, great emphasis is placed on practical classes. Practical classes are performed in two ways. During laboratory classes, students are taught modelling and conducting simulation research, which has been described in detail in [9]. The second form of learning power electronics is to experience it in a practical way at laboratory stands with equipment enabling testing various types of power electronics converters. Laboratory classes encompass twelve exercises that are performed by students for 30 hours. Each exercise is intended for two lesson hours in a group of two or three people. It is not possible for the exercises to be performed by one person on account of their scopes. Exercises are performed rotationally and four to six laboratory stands are occupied simultaneously during one meeting. Laboratory classes require the presence of two people, which is why an academic teacher is usually accompanied by a technical worker. This requirement is due to the fact that students work with high voltages, which in some cases can reach 500 V.

Students have at their disposal manuals that contain theoretical information about each exercise and schematic diagrams (Fig. 1) as well as diagrams that show the connections on the training modules (Fig. 2).

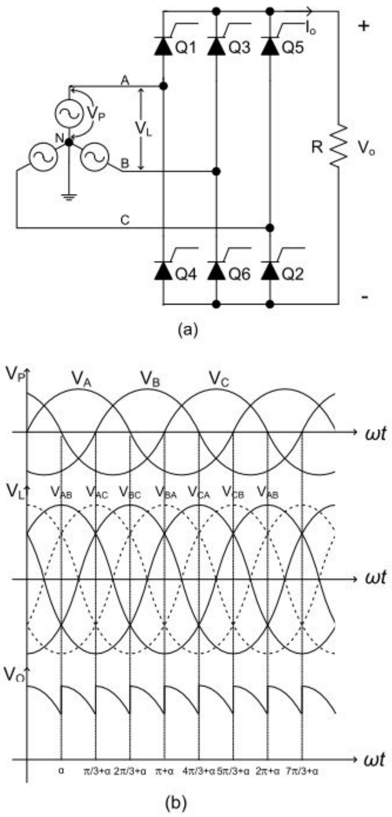

Fig. 1. The example schematic diagram of the three-phase full-wave controlled rectifier obtained from the laboratory manual

The exercises which are realized in the laboratory are as follows:
1. Measurements and characteristics of the SCR thyristor, triac, MOSFET and IGBT transistors;
2. Testing the operation of single-phase half-wave and full-wave controlled rectifiers with resistive and resistive-inductive loads;
3. Testing the operation of single-phase half-controlled and fully controlled AC voltage controllers;
4. Testing the operation of three-phase half-wave and full-wave uncontrolled rectifiers;
5. Testing the operation of a circuit of a single-phase PWM modulator and a single-phase voltage source inverter;
6. Testing the operation of BUCK and BOOST DC-DC converters;
7. Testing the operation of single-phase full-wave controlled symmetrical and asymmetrical rectifiers;
8 Testing the operation of three-phase half-wave controlled rectifier, full-wave half-controlled rectifier and full-wave controlled rectifiers;
9. Testing the operation of three-phase half-controlled and fully controlled AC voltage controllers;
10. Testing the operation of one-quadrant and four-quadrant transistor choppers;
11. Testing the operation of a three-phase PWM modulator and three-phase voltage source inverter;
12. Testing the operation of BUCK-BOOST and FLY-BACK DC-DC converters.

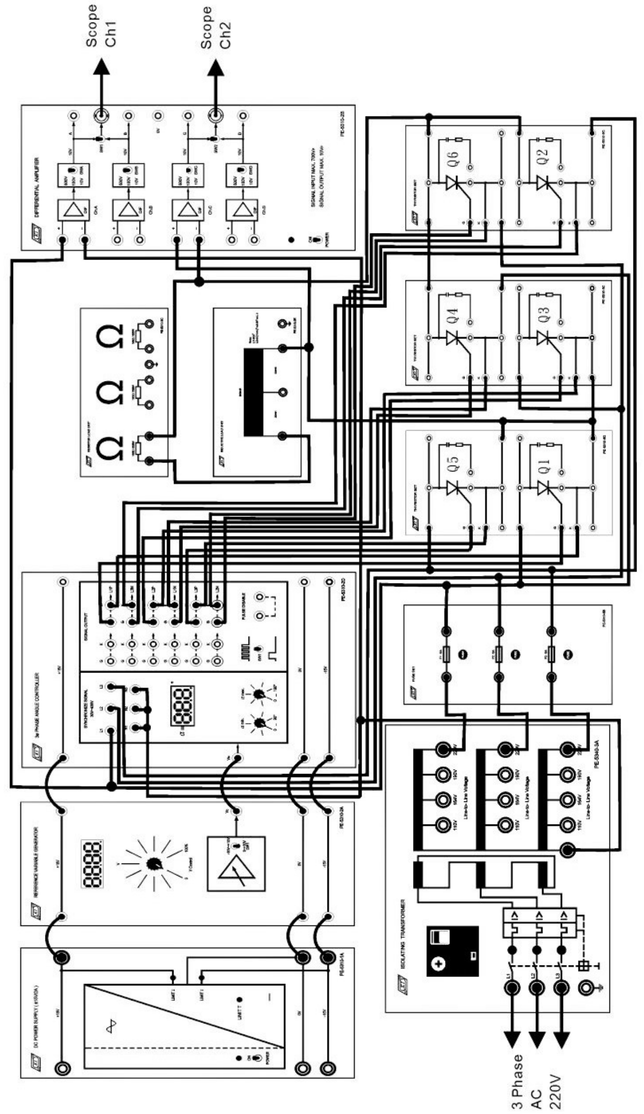

Fig. 2. The example installation diagram of the three-phase full-wave controlled rectifier obtained from the laboratory manual

The work scenario for each of the exercises includes checking the knowledge and preparing students for classes, then discussing individual exercises and connecting the wiring on the basis of diagrams. The connections at particular stands are verified by the academic teacher and only when they are proper, the students proceed to the measurement part, which they conduct in accordance with the instructions and teacher's remarks. During the exercises, students prepare a measurement report. Some of the results are archived by students on flash drives because they are in the form of oscilloscope screenshots. Various forms of data registration are important for the work of modern engineers since they will use them later. An example is the remote measurement systems using Internet transmission.

Power electronics training modules

Power electronics training system utilized in the laboratory was produced by K&H products company. The laboratory is well-secured. The particular stands are isolated from each other by transformers and switchboards. Figures 3 and 4 show the illustrative laboratory stands. They contain extensive measuring apparatus, such as oscilloscopes, meters, multimeters. Moreover, students make measurements using voltage (LEM) and current (Hall) transducers. What is more, some laboratory stands are equipped with low-power DC and AC electric motors. This provides young engineers with knowledge about the operation of electric drives.

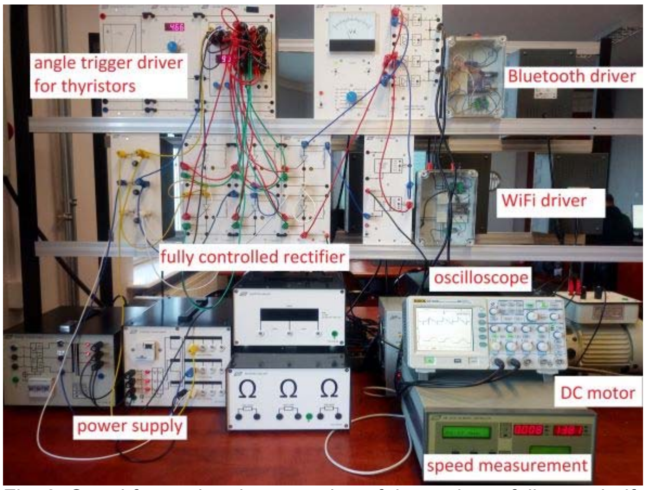

Fig. 3. Stand for testing the operation of three-phase full-wave half-controlled and fully controlled rectifiers, whose control can be conducted in either a local or remote way

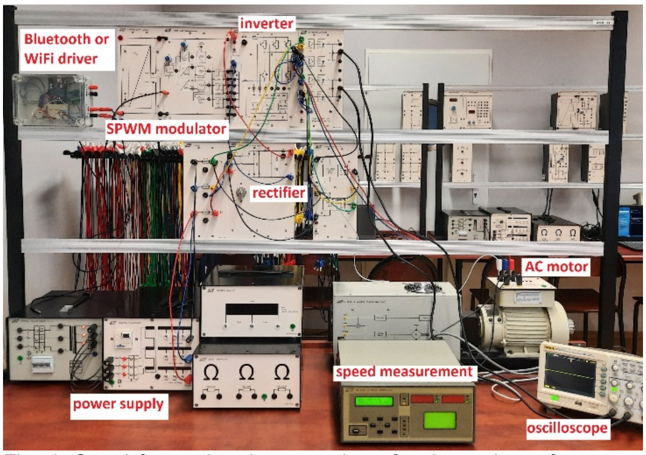

Fig. 4. Stand for testing the operation of a three-phase frequency converter, whose control can be conducted in either a local or remote way

An important feature of the laboratory stands is that they are modular in the form of panels which represent various elements of the system such as diodes, thyristors, single-phase PWM modulator, reference voltage power supply, etc. All panels are mounted in aluminium profiles that ensure high stability and comfort of work. The modules can be combined in diverse configurations to obtain systems containing various converters, taking into account also the required measurements. Panels are designed in such a way that they have a diagram of a given element drawn along with the places of connecting points. Presenting a given element in an ideological way allows students to associate particular converters with their schematic diagrams (Fig. 1) whereas the installation diagrams (Fig. 2) allow understanding of the individual stages of the exercise as well as the performed measurements. However, the disadvantage of this approach is that students often do not know what the actual appearance of individual elements of the system is.

Analysis of the results of the conducted surveys

Survey research has been conducted in order to obtain information on the opinions and experiences of students who have participated in power electronics laboratory classes with the use of training modules. The surveys were conducted among Electrical Engineering bachelor students at the end of the summer semester in the academic year 2021/2022. In the beginning, it should be emphasized that the questionnaire was filled in by 52 students who joined all laboratory exercises assumed in the power electronics course curriculum. Questions contained in the survey were multiple-response and some of them allowed giving additional opinions.

The achieved results have shown that the vast majority of students prepared themselves for the classes mainly from the laboratory manuals (98%) and occasionally from additional sources such as books or articles. During the semester, students performed particular exercises in groups of 2 or 3 people, but occasionally, for example as a result of illness, they had to do classes alone. On answering the questions, they have declared that the optimal number of people in a laboratory group is 2 or 3. This has confirmed the validity of the approach used so far. Students also had the opportunity to express their opinion on the question of whether this form of laboratory stands did not limit their creativity in connecting individual power electronics systems. Most of them have responded that not, thus providing that the training modules do not limit students' work, and on the contrary, they encourage them to develop their technical skills. An interesting answer was given by students to the question in which they were asked whether the lack of actual elements, which were replaced with a schematic diagram drawn on the panel, pose a problem in performing the exercise in terms of connecting and understanding the principle of operation. The vast majority of students decided that the diagrams drawn on the panel housing did not hinder the execution of the exercise. What is more, they do not interfere with comprehension of the operation of particular elements and converters, but even help students relate the theoretical knowledge to the practical applications.

Further questions, which were concerned with laboratory manuals, have indicated that students found them coherent and understandable. These instructions allowed students to prepare well for the performed exercises. Students, particularly, have drawn attention to the theoretical descriptions contained in the manuals as well as the fact that they included example results and waveforms, which helped them verify their own measurements.

According to the students, the laboratory stands in the form of modules made the registration of the required electrical signals easier. Moreover, such a solution facilitated the inspection of the correctness of connections and the entire control system. Students have stated that this form of laboratory stands ensured a relatively easy way of finding mistakes in connections, which resulted in avoiding damage to the systems. Therefore, due to their construction, training modules increase the level of work safety during exercises.

The last question of the survey was focused on the overall impression and advantages of working at laboratory stands based on panel modules. Students had to rate their general opinions on a scale of 1 to 5, in which 1 denoted a negative assessment whereas 5 was a very good one. The distribution of the answers has clearly shown that over 80% of students praise this design of the power electronics laboratory stands.

Conclusions

Teaching power electronics is demanding and requires both theoretical and practical background. Hence, a well-equipped laboratory is an important issue. Laboratory stands which allow students to connect particular elements independently in order to build power electronic systems are especially significant. An example of such an approach constitutes training modules presented in this paper. Not only are they meaningful from the point of teachers' view, but they have also gained recognition from students. The latter inference has been obtained on the basis of conducted surveys. Acquired answers have shown that utilized training modules are useful in learning power electronics because they help relate theoretical knowledge with practical aspects. The confirmation of the legitimacy of performing laboratory classes with the use of this kind of equipment is meaningful as students are the ones who should benefit the most from working in this kind of laboratory.

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