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The Use of VR Technology in Teaching Electrical Power Engineering on the Example of the VES Application

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Abstract

The article presents the use of virtual reality (VR) technology in the process of teaching electrical power engineering, based on the Virtual Electrical Switchgear (VES) application. The author discusses the advantages of using VR in education, pointing to interactivity, the possibility of carrying out practical tasks and improving student engagement. The functions of the VES application were also presented, which allow the simulation of realistic scenarios related to learning how to build and operate MV switchboards. The article also includes research results confirming the effectiveness of using this application in the teaching process, including increasing the effectiveness of learning and improving students' understanding of issues. An important perspective for the development and further use of VR technology in the field of teaching electrical power engineering was noted, contributing to improving the quality of education in this field.

Keywords: Virtual Reality, VR in education, teaching process, higher education didactics

Introduction

After the crisis related to the Covid-19 pandemic and the outbreak of the war in Ukraine, the accompanying reorganization of the global supply chain and rising inflation, energy instability and lack of trained staff have been added to the challenges of the industrial sector. Compared to the 2015/16 academic year, where the total number of students in Poland was 1,405.1 thousand, in the 2022/23 academic year, 1,223.6 thousand people studied (Statistics Office in Gdansk, 2023). According to the assumptions of the European Commission "Education and Training 2020" and the report on the Agenda for the Modernization of Higher Education (European Commission, 2011), higher education faces many important problems. One of the main challenges is, among others, impro-

ving the quality and relevance of teaching and learning. Market expectations towards universities seem to be unchanged and are expressed in qualified, competent, innovative and talented graduates. Students are future knowledge workers and, after completing their studies, they should have thorough education, knowledge, practice and experience in a specific field. Graduates broadly educated and prepared to take up work will have an impact on the economic development and prosperity of the European market. However, the potential of European higher education institutions in terms of their role in society and their ability to contribute to Europe's prosperity is not fully exploited. Research under the Human Capital Operational Program in 2014 showed that nearly 80% of employers reported problems with finding qualified employees. Internal research among students indicates a high demand for practical exercises, which the university is unable to provide due to limited staff and equipment resources. It seems that the implementation of digital teaching techniques, including virtual reality, can help universities increase the attractiveness of classes and improve the quality of teaching.

Virtual reality (VR) is a technology that provides an interactive computer-generated environment, usually with a dynamically changing scenario, in which you can see and move. VR simulates the user's physical presence in an artificially created world and allows him to interact with this virtual environment (Bowman, McMahan, 2007).

This article explores the utilization of VR technology in teaching electrical power engineering, focusing on the innovative VES application as a case study. By leveraging VR, educators can provide students with dynamic, interactive, and realistic simulations that closely mimic real-world scenarios encountered in the field of electrical power engineering. Through VES, students can engage in hands-on experiences, such as troubleshooting network failures, conducting equipment maintenance, and navigating complex electrical systems, all within a safe and controlled virtual environment.

VR technology in education

Virtual Reality (VR) technology has emerged as a powerful tool in various fields, revolutionizing the way we perceive and interact with digital environments. In the realm of education, VR holds immense potential to transform traditional teaching methodologies, offering immersive and experiential learning experiences. One area where the application of VR technology showcases significant promise is in the domain of electrical power engineering education.

VR is used in those industries where making a mistake may result in damage to health or exposure to costs related to the destruction of equipment, like electrical power engineering. Due to the affordability and wide range of possibilities of this technology, it is gaining more and more popularity all over the world.

Among others, Schneider Electrics used virtual reality as a training medium in the field of electrical power devices offered by the company (Schneider Electrics, 2022). Another example of the use of virtual reality in practice is a project implemented by Enea Operator, consisting in mapping a training means for learning work under voltage. This project involves the development of training scenarios for selected Main Power Supply Points and MV stations (Enea Operator, 2019).

The integration of VR technology into the teaching of electrical power engineering offers numerous benefits, including enhanced student engagement, improved comprehension of complex concepts, and the opportunity for practical skill development. Additionally, VR facilitates personalized learning experiences, allowing students to progress at their own pace while receiving immediate feedback and guidance.

This article not only discusses the functionalities and capabilities of the VES application but also presents empirical evidence supporting its effectiveness in enhancing the learning outcomes of students in electrical power engineering education. Furthermore, it explores the potential implications and future directions of VR technology in advancing pedagogical practices within this field.

VES application

The main goal of the VES project was to develop and implement an innovative platform for cognitive training using VR and AR technologies for a virtual laboratory of power equipment. As a result of the project, an innovative application using VR technology was created, intended for learning the construction and operation of, among others, MV switchboards and an application for mobile devices using AR technology.

The main aspect of the VES application that was used for the work is the virtual model of the medium voltage (MV) switchgear. A switchgear is a set of electrical power equipment operating at the same rated voltage, used to distribute electricity. It consists of a structure equipped with busbars and insulating elements, as well as electric power equipment serving as distribution, protection or measurement (Elektrometal Energetyka S.A., 2021). The MV switchgear implemented in the application is based on the real model of the switchgear produced by Elektrometal Energetyka S.A. presented in Figure 1.

MV switchgears with power equipment are characterized by characteristic electrical quantities, the values of which depend on the method of execution, electrical solutions and materials used. These values are crucial when selecting the equipment, and the designers make every effort to achieve the highest possible values of current, voltage or temperature to which the switchgear will be adapted, while keeping its dimensions and production costs as small as possible.

Figure 1. MV switchgear from Elektrometal Energetyka S.A.: on the left pic taken in the Laboratory of Power Apparatus and Switching Processes, on the right from (Elektrometal Energetyka S.A., 2021): A – control circuit compartment, B – busbar compartment, C – mobile module compartment, D – connection compartment.

For the proper functioning of the VR application, a set of necessary devices was used, which included:

– VR glasses, two touch controllers included in the Oculus Quest 2 set,

– A computer equipped with a modern processor and graphics card, with sufficient computing power,

– Monitor displaying a view from the perspective of using VR glasses, used to analyse the respondent's movements in real time,

– Router for exchanging information via WiFi between the computer and the VR set.

The created laboratory stand is shown in Figure 2. In the further description of the application, for easier identification, the user is the person who is currently using VR glasses, and the avatar is the character that the user moves in the virtual world.

Figure 2. Laboratory setup in the Laboratory of Power Apparatus and Switching Process

The start screen, shown in Figure 3, consists of a tutorial button and 3 functional levels of the application. It is additionally possible to select the application language, i.e. Polish or English (upper right corner of the board). The table is additionally used as a source of information regarding switchboards, i.e. general information regarding MV switchboards, individual requirements and rated parameters, as well as standardization and certification.

Figure 3. The start screen of VES application

By embedding 3D models of devices in virtual switchgear rooms (e.g. in those modelled on real industrial facilities), separate functional parts of the switchboards and components (e.g. switching devices, bus systems, measuring transformers) were visualized. The individual functional elements of the switchboards and the power supply system itself are presented in the form of an interactive single-line diagram. The diagram will enable you to link the symbol used in it with the corresponding switchgear element.

The VES application consists of the following levels of training and functional VR simulations:

1) Level I – Construction of elements of the energy distribution system and switching activities during normal operation of the system (Figure 4),

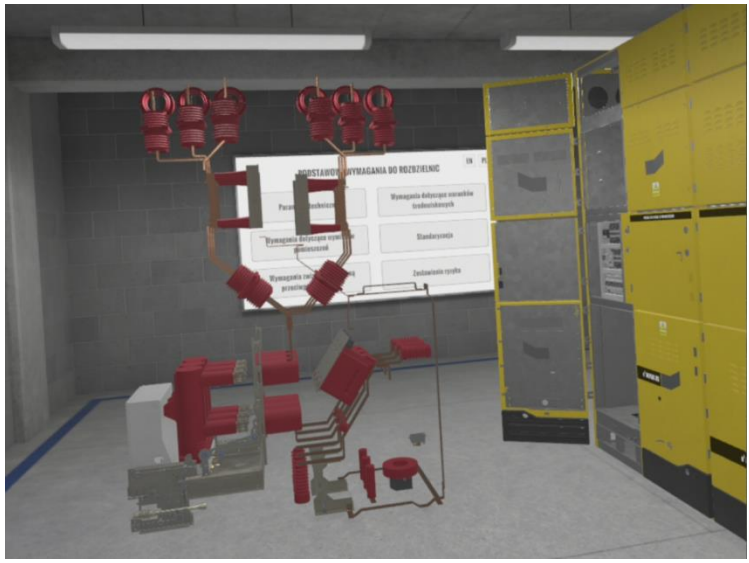

Figure 4. A screenshot from the Level I part of the VES application

2) Level II – configurator of MV switchgear systems (Figure 5),

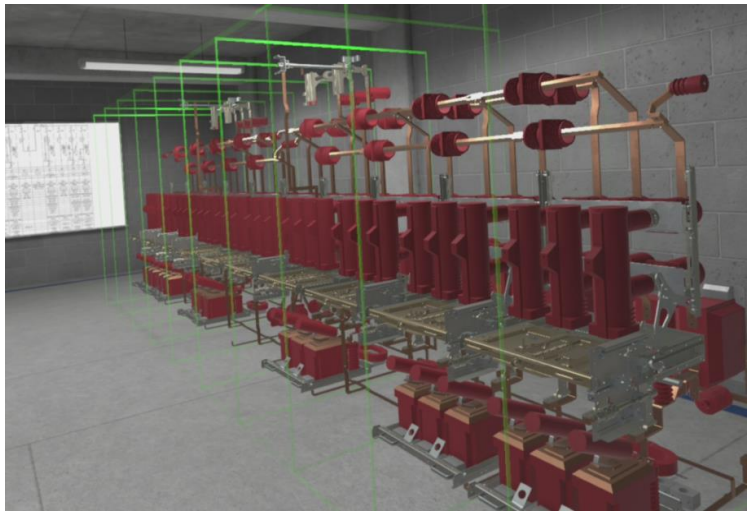

Figure 5. A screenshot from the Level II part of the VES application

3) Level III – building the right platform for cognitive training (Figure 6).

Figure 6. A screenshot from the Level III part of the VES application

VES application tests at WUT

In the 2023/24 academic year, initial tests of the VES application were carried out in academic and industry environments. 16 questions were developed and the test participants (51 people in total) answered them after working with the VES application for 20 minutes. Below are the results of the most important survey questions.

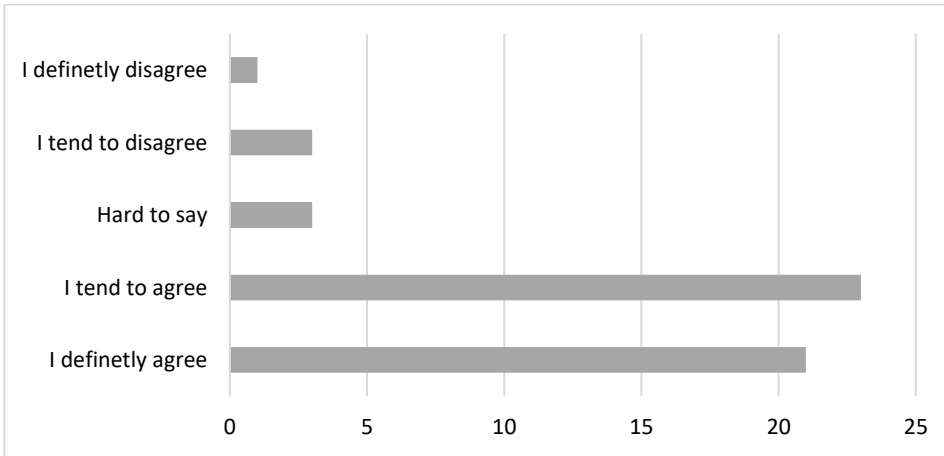

Figure 7. Results of answers to issue 1 – I feel that I have gained new knowledge

Most test participants appreciated the possibilities of using VR technology in science and felt that they had gained new knowledge related to the construction of MV switchboards (Figure 7). Immersive VR experiences can be extremely motivating for students because they provide exciting and interesting ways to learn (Figure 8). This can help increase student engagement and encourage them to explore the topic further. Most research on VR technology confirms that it can use different senses to provide a more integrated learning experience and that it requires greater concentration, which translates into higher educational value. Most also confirmed that the application itself does not cause excessive discomfort related to the use of VR technology (Figure 9).

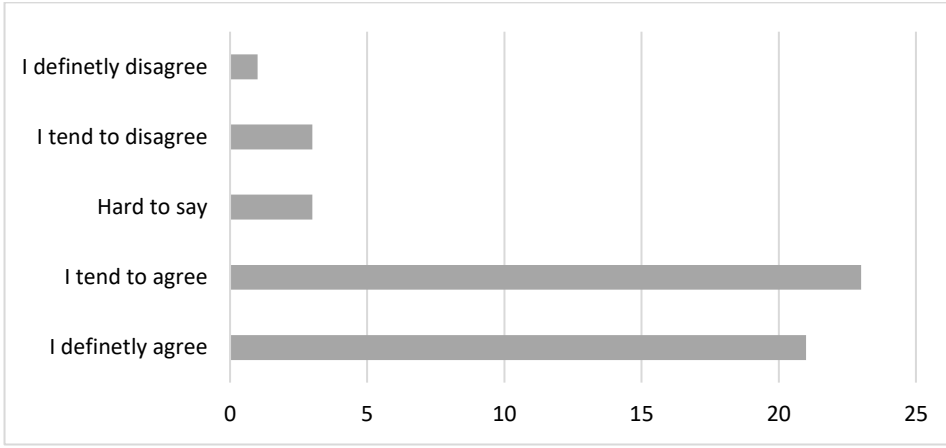

Figure 8. Results of answers to issue 6 – VR exercises required more concentration from me than if they took place in reality

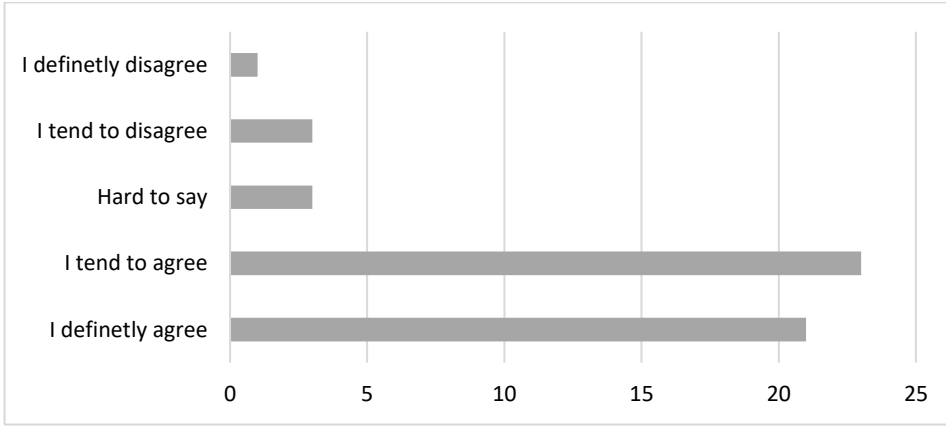

Figure 9. Results of answers to issue 7 – My level of concentration during the exercise was high

Conclusions

This publication explores the development and utilization of a VR application designed to enhance the learning experience of construction and operation procedures for MV switchgears, which are critical components in the electrical power distribution systems, and ensuring safe and efficient operation is of paramount importance. Research related to the VES application has led, as confirmed by experience (ENERGETAB fair 2022, 2023), to the introduction to the educational and research market of a unique and innovative product and service that will be used in training knowledge and skills in the construction and operation of power equipment. Available literature and market research show that this will be the first product of this type available in Poland. This will also allow for the creation of a new quality of academic teaching and research and development work. A qualitative change in conducting laboratory classes will allow for better results in the education of future engineering staff.

Overall, the integration of VR technology, exemplified by the VES application, represents a paradigm shift in the way electrical power engineering is taught and learned. By harnessing the immersive capabilities of VR, educators can cultivate a dynamic and engaging learning environment that fosters critical thinking, problem-solving skills, and real-world applicability, ultimately shaping the next generation of electrical power engineers.

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