SYSTEM SAFETY: HUMAN - TECHNICAL FACILITY – ENVIRONMENT
7(1), 2025, pp. 453-464

USAGE OF A VIRTUAL ELECTRICAL ENTERPRISE AS MEANS FOR THE FUTURE POWER ENGINEER PRACTICAL TRAINING

DOI: 10.2478/czoto-2025-0042
Received: 09/11/2025
Accepted: 16/12/2025

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Abstract: In the context of an increase in the share of distance learning the educational institutions that train specialists in the field of power generation, use and supply are faced with certain difficulties in conducting practical training for students. This article discusses the features and stages of creating virtual enterprises as a tool for the practical training of future power engineers. The authors propose a scalable and adaptive solution: the implementation of a "Virtual Electrical Enterprise" using virtual reality (VR) technologies and specialized software for immersive and interactive practical training. The system simulates various departments of a real production enterprise and allows students to perform professional tasks in a controlled virtual environment. A partial experimental evaluation was conducted to evaluate the effectiveness of this approach, demonstrating improved learning outcomes, heightened student interest, and the potential to compensate for limited access to real industrial equipment. The proposed system not only enhances student preparedness for future employment but also offers prospects for lifelong learning and closer collaboration between universities and industrial enterprises. Future work involves the progressive implementation of this concept into the educational process for electrical engineering students

Keywords: virtual enterprise, virtual electrical enterprise, virtual reality, practical training of electrical engineers

1. INTRODUCTION

Due to the significant economic competition in the market, the owners of the production works place high demands on the level of practical literacy of higher education institution graduates. So students must have a significant amount of practical skills in their specialty that allows them to successfully compete in the labor market with other job seekers.

This is the reason why universities must strengthen the practical training of future power engineers during their studies. The university educational and professional programs for the undergraduates and graduates traditionally provide a number of practices (typically three or four for the undergraduates and one or two for the masters) with the usual duration in two or three weeks). During the practices the student must acquire the basic working skills with production and auxiliary equipment in accordance of the labor market demands, establish and identify ways and methods for applying of the theoretical knowledge given to them in higher educational institutions in modern practical production, get a chance to outline their career paths and see those gaps in the practical and theoretical training provided by educational institutions that should be filled later, etc. However, it is usually impossible to fully cover the necessary skills during these training periods due to their short duration, the limited production profile, and the insufficient technical equipment of the enterprises typically used as practice bases.

The lack of the acquisition of the mentioned skills can be partially compensated by the student practical trainings in the laboratory and the practical classes held on the own base of their educational institutions. For this purpose, the material base of these classes must be at the superb level, so they must be equipped with the modern production equipment that, moreover, must be periodically updated for the keeping it up to the level of the contemporary and the future demands. So, this presents a problem because this material base would be rather expensive and therefore usually it would not fully feasible in practice neither for any leading Ukrainian educational institution nor for the rather advanced Western university.

Over the past three years, due to the COVID-19 epidemic and the war outbreak, these problems have only worsened due to the forced increase in the share of the distance learning with difficult access to laboratory and practical classes in the educational institutions and some decrease in the opportunities for the training practices organization of at enterprises as the practice bases.

The said above shows that there is an educational and methodological problem of increasing the practical training for students and the essence of the problem is the insufficient level of the gained professional practical skills acquired during the educational process of students. One of the reasons for this problem is the low level of classroom class provision with modern production equipment.

One of the possible ways to solve this problem is the virtualization of production equipment and the introduction or development of virtual reality (VR) devices and the appropriate software. Therefore, this paper proposes one possible way to use the mentioned above technical means for the practical training virtualization.

2. BRIEF HISTORICAL REVIEW AND FORMULATION OF THE RESEARCH OBJECTIVE

It should be noted that the idea of the replacing direct human interaction with technical systems under the real conditions by an artificial environment, where such interaction in complex and dangerous situations is imitated by a simplified technical simulator system, is not new one and has more than 60-70 years of background – we could primarily recall the simulators for training of vehicle operators, military, police, etc (Anderson & Elloumi, 2004; Tzafestas, et al., 2006; Rosenberg, 2000). It is also obvious that idea of the practical training for future engineers is directly based on the experience of distance learning accumulated over the past 25-30 years, which has gradually developed in parallel with widespread use of the World Wide Web (Zaimovic-Uzunovic, et al., 2001; Yeung, Huang, 2001). This idea has gained more real contours with the emergence and development of hardware and software virtualization at the level of virtual reality (VR) and the Internet of Things (IoT) (Middlehurst, 2014; Guo, et al., 2021; Pimentel, et al., 2018; Gillich, et al., 2010). Current research confirms that the ubiquity of such technologies, including VR and automation, is fundamentally reshaping the socio-economic environment and the way individuals function within technical systems (Suchacka, et al., 2023). Furthermore, in the emerging Industry 5.0 concept, the focus shifts significantly towards a human-centric approach, where ensuring a safe working environment and developing appropriate human skills interacting with cyber-physical systems become paramount (Saniuk, et al., 2024). New industrial paradigms have redefined not only the structure of production but also the nature of human interaction with technology, where the most important organizational aspects concern the use of navigation and management of business activities mainly through smart devices (Avşar, 2025). It's clear that VR training implementation cannot completely replace the training at a real work site (Qawaqzeh, et al., 2021; Sirohi, et al., 2020; Khasawneh, et al., 2021), but it can serve as a serious help in such training, primarily in terms of improving the level of labor protection and safety (Almarshoud, 2011; Ali, 2020; de Sá, et al., 2025). This correlates with findings indicating that the introduction of Industry 4.0 technologies and process automation significantly reduces occupational risk by minimizing exposure to hazardous factors (Klimecka-Tatar, et al., 2023). However, evidence from technology 4.0 implementation contexts indicates that while advanced technologies can reduce some direct exposure risks, they may also introduce new safety challenges and therefore require comprehensive training and safety standardization (Pilarczyk & Ulewicz, 2024). So, now the world's leading electrical companies are implementing such a training for their practical activities (Lyngdorf, et al., 2024; Lezhniuk, et al., 2020; Schneider Electric; Al-Issa, et al., 2022; Groove Jones, 2020). At the same time, the authors of this article set the task to develop a more comprehensive and scalable approach to teaching power engineering students using virtual enterprises in the conditions of higher educational institutions (Tan, et al., 2022; Murugan, et al., 2025).

3. GENERAL DESCRIPTION

The technical means that are proposed to be used for training in a virtual enterprise are a computer, virtual reality tools (helmet and / or glasses, gloves, boots, ideally a special suit that includes a helmet, boots and gloves), as well as software that allows the recreation of various electrical objects in 3D and work with them.

The initial methodological tool (which is planned to be developed and expanded as experience and learning results accumulate) for the practical training of electrical students is the business game called "Virtual Enterprise" that provides services for the creation and maintenance of electrical objects. Such utilization of didactic games and training platforms creates a comprehensive teaching process, effectively filling the gap in the new paradigm of education for Industry 4.0 (Gąbka, Przybyś, 2025).This virtual enterprise has the following departments: design, installation, commissioning, operation, repair - each of them is based on one or more professionally oriented disciplines (Fig. 1). Each department performs its own function, but they all work for a common goal - ensuring the efficiency of the enterprise, which refers to the production of any type of production (electricity, food products as a result of processing, metalworking products, etc.). The efficiency of the enterprise is determined by the productive work of each department: the better the departments work, the more products the company produces.

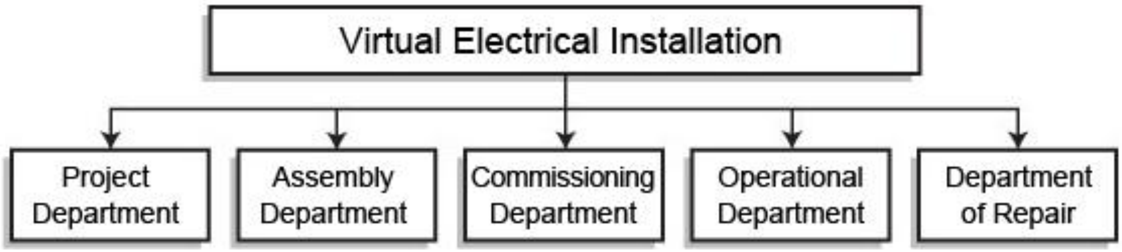

Fig. 1. The block diagram of the structure of the virtual electrical enterprise

It should be noted that as the virtual enterprise improves as a technical and organizational system with the involvement of the efforts of the teaching staff involved in the training of other specialties students, it seems promising to expand the enterprise functionality to train other specialties (mechanical engineers, designers, technologists, specialists in labor protection, etc.), taking into account the specifics of their training and possible mutual interaction with the aim to make the system closer to the conditions of real production.
The head of the enterprise is the educational and professional program guarantor. According to the student's program, the head of the department is the teacher who teaches students the appropriate professionally oriented discipline of the program. Employees of the departments are students who study under current program. The role of the head of the enterprise is to coordinate the activities of the heads of departments (establishing the sequence of studying disciplines, coordinating work programs and teaching materials) and providing conditions for mutual fruitful work with other participants in the educational process: the dean, heads of departments, academic department, etc. The role of the head of the department is to manage employees in the department and, in parallel, train them in the form according to the professional virtual game. The role of the employees of the department is the performance of a certain type of work assigned to him by the head of the department.

4. GENERAL DESCRIPTION THE SCENARIO EXAMPLE FOR THE VIRTUAL ENTERPRISE USAGE FOR PRACTICAL TRAINING OF STUDENTS

Before doing work in any department, employees (students) improve their skills: possibly, they may listen to a lecture on the relevant discipline, where they receive explanations of the theoretical material necessary to complete this work. When they rework through this material at home according to the guidelines compiled by the supervisor – the department head (teacher) - assignments. Having improved their qualifications in this way, they start working in the department, so they start their laboratory or practical lesson. This activity can be called "Performing such and such work in such and such a department". First, they receive admission to make an implementation by confirming their qualifications by testing on a computer according to the studied lecture material. Further, the head of the department (teacher) divides the employees (students) into working teams and sets a task for each team (gives assignments) and monitors the progress of the implementation and advises employees as soon as any question arises. During the working process all or only some of the technical means mentioned above are involved. The work is carried out virtually in a computer program that has a number of built-in applications for performing individual operations. The result of work is evaluated in points by the same computer program taking into account the speed and the correctness of the completed task. The points are awarded for the completed task only. At the end of the semester within each department, students receive grades according to the points scored. The mentioned grades could be both reflected in their grade lists and in ranks that allow them to move up to the career ladder of the enterprise – for example, to become a foreman or assistant to the head of the department, etc.

In more detail description, it goes like this: in the design department each of the teams designs the electrical part of a working machine and sends the design to the installation department, where both the electrical part of the working machine and the apparatus as a whole are installed (installation on the base and the connection with others working machines, etc.). This happens as follows: department employees (students) who have confirmed their qualifications (passed a computer test for the current material) receive from the head of the department (teacher) the task to install some working machine, which was designed by one of the teams of the design department. Each of the teams of the assembly department determines the list of operations that they need to perform as well as the tools and fixtures to perform these operations. This is done by selecting operations and tools on the appropriate tabs of the computer program, where students can also remind or familiarize with the content of mounting operations and the image and technical characteristics of mounting tools and fixtures. After confirming the choice of operations at this stage the program determines the correctness of the list and sequence of the selected operations and informs the students about this. If an error occurs during the selection the students specify it and this fact follows to the decrease in the received score. The same happens with the choice of tools and fixtures. In case of an error you can use the advice of the head of the department (teacher). Next, the team distributes the total amount of work among its individual members (Fig. 2 and Fig. 3). After that students get equipped, put on virtual reality costumes, and start to work. They have a 3D image of the workshop room before their eyes, where the working machine and individual components of the electrical part are located as well as images of the necessary tools and auxiliary mechanisms. Using these images, workers (students) proceed to the installation, performing the operations that they foresaw in advance. If the installation of the equipment is not done correctly, the program informs the employees about it and they fix the problems - also with affects the points they earn. If students do not have enough time to complete the equipment installation up to the end of the lesson, the program stops their work and offers the possibility to come for a consultation to complete the installation., The students are not allowed to complete the next task without completing this work. The computer program used in the lesson is constantly updated with individual components that visualize mounting tools, fixtures, etc., allowing the students to work with the most modern technical means (Fig. 4).

Fig. 2. Virtual reality tools

Fig. 3. Program interface (page for installation operation selection)

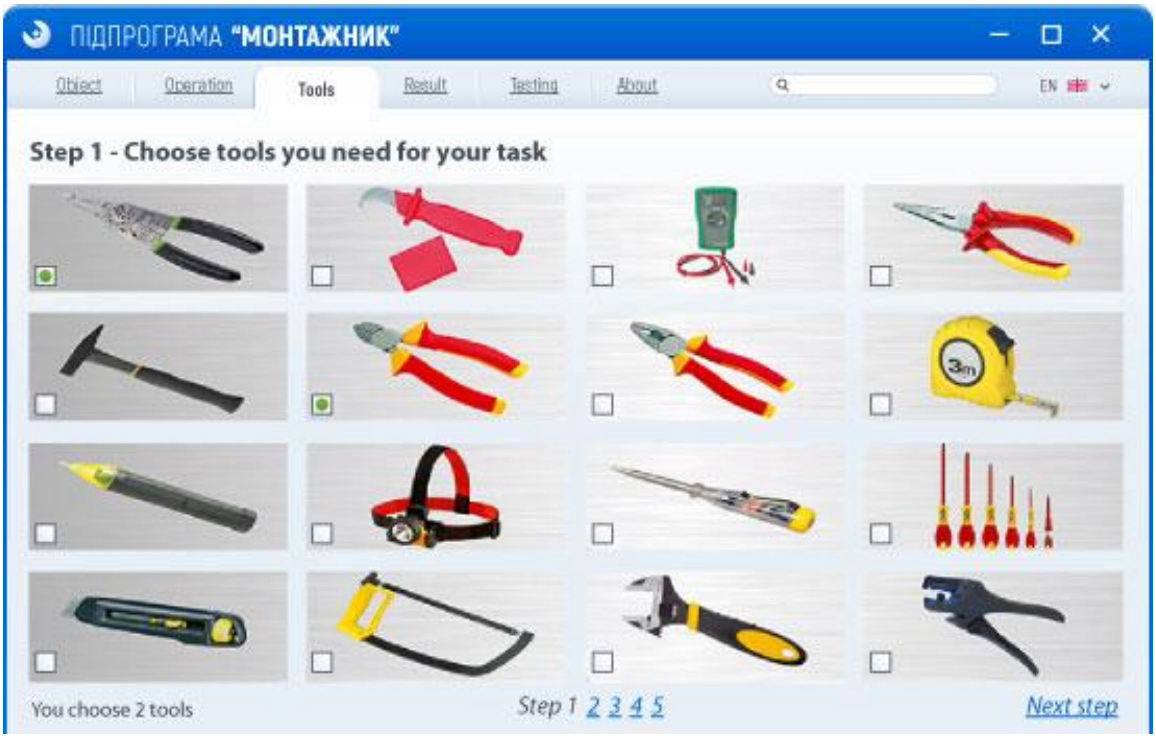

Fig. 4. Program interface (page for installation tool selection)

5. THE PARTIAL EXPERIMENTAL CHECKING

The authors of the article conducted an experimental test of a fragment of the proposed business game. The purpose of the test was to estimate the influence of virtual reality on students' learning of the material. Some students studying the discipline "Installation of electrical equipment and automation equipment" (2nd year students) were chosen as installation department (Miroshnyk, et al., 2023; Kanematsu, et al., 2023; Bazaluk, et al., 2022a; Vovk, et al., 2019).

At the first stage a circuit diagram for controlling the electrical equipment of the milk preparation section of the pasteurized milk production workshop was selected as an object for installation. At the second stage, methodological recommendations were drawn up for conducting classes on the installation of this control circuit. At the third stage, a fragment of a computer program was developed using Unity platform (Al-Quraan, et al., 2022; Tymchuk & Miroshnyk, 2015a; Markowska, et al., 2024). It allows to select tools for installation in 3D mode using virtual tools and get acquainted with their technical characteristics, compile a list of installation operations and repeat their essence, carry out installation of low-voltage electrical equipment (like installation of sensors on working machines, fastening magnetic starters, connecting elements to each other, etc.) for the developed electrical control circuit diagram (Trunova, et al., 2021; Hesselink, et al., 2003; Saad, et al., 2002). At the fourth stage, a methodology was determined for assessing the effectiveness of using a fragment of a computer program for assembling an object in training (Rubanenko, et al., 2017; Sanchez, et al., 2004). For this stage the students were divided into 4 groups (one for the experimental approach and three others for control) for mounting identical objects twice (Lezhenkin, et al., 2021; Tymchuk, Miroshnyk, 2015b; Bazaluk, et al., 2022b). The first access was a training one; the second access was a control one. Students of one group (hereinafter referred to as the first group in the following tables) in the first access performed editing in a developed program using virtual reality tools, and in the usual way in the second access. Students from other groups in both accesses performed the installation in the usual way. The usual method was to install the specified circuit on the existing stand in the educational institution using existing tools. The correctness and speed of installation of electrical equipment and its quality were assessed during the experiment. The criterion for the performed work correctness was the correct startup of electric motors in accordance with technical and technological requirements. As a result of the experiment, it was necessary to determine the following: 1) how much the assembly time of the circuit of the first group in the control approach would be differ from the other groups (possibly, much longer); 2) how will the quality of installation of the first group in the control approach differ from the other groups (possibly, much worse).

The students were divided into four groups of 5. Testing students at the beginning of the lesson regarding their preparation showed approximately equal results (Table 1).

Table 1. Results of preparing students for the lesson

Indicators	1 group	2 group	3 group	4 group
Academic performance, %	80	100	100	80
Quality, %	60	60	80	60

Then the students from each group carried out two approaches to installing electrical equipment with a 10-minute break between. The installation time spent by students of each group on in the second access is shown in Table 2.

Table 2. Installation time

Indicators	1 group	2 group	3 group	4 group
Installation time, min.	65	68	61	64

The data in Table 2 show that the circuit assembly time for all groups is within acceptable limits and the circuit assembly time for first group students has no drastic difference from the average.

An assessment of the quality of the installation performed (equipment fastening strength, intersection of connecting wires, etc.) in the second approach is shown in Table 3.

Table 3. Installation quality

Indicator	1 group	2 group	3 group	4 group
Installation quality	good	satisfactory	excellent	good

So, the quality of the installation performed in all groups is within acceptable limits. At the end of the lesson, the emotional state and interest of students, which was assessed based on the survey results, was higher in the first group compared to students in other groups. The obtained results indicate that the developed fragment of the business game “Virtual Electrical Engineering Enterprise” makes it possible to improve the quality of student learning through constant updating of the virtual database with new technical means and technologies and the interest of students in the material under consideration through the use of a game form of learning that is close to reality. Thus, the use of virtual programs for training makes it possible to significantly save the material resources of an educational institution without deteriorating the quality of education and to consider advanced techniques and technologies in the classroom.

5. CONCLUSION

The advantage of the proposed system for training power engineering students in a virtual enterprise created within a higher educational institution lies in the fact that it scalable, expandable and continuously improvable, and can also be adapted for teaching students of other specialties.

The authors are aware that a virtual enterprise cannot completely replace the practical training of future specialists in real production conditions. However, it can significantly complement the level of students' skills and allow them to come to real production site with better preparation and thereby providing opportunities for more effective use of a fairly short period of industrial practice due to a significant reduction in the time required to adapt into production realities. In addition, the creation a virtual enterprise makes possible and necessary to use the experience of the most advanced real enterprises, which is not yet available for those enterprises that are the direct base of practice. Moreover, such a virtual enterprise can serve both as a means of improving the skills of full-time employees of the enterprises served as a base of practice within the framework of the concept of "lifelong learning" and as a means of increasing mutual interest and interaction between a higher educational institution and industrial enterprises (Kuzior, et al. 2024).

Our plans include the embodiment of this idea in the educational process within the framework of the educational and professional program of specialty G3 "Electrical Engineering" at the faculty. At the moment, we have moved from an idea to its implementation (like mentioned here partial checking and elaboration for some units). The implementation of the idea into reality consists of the following stages:

1) development of the structure of the enterprise and the definition of the functions of its departments;

2) drawing up assignments for each of the departments, determining the technical means for their implementation and establishing criteria for evaluating students;

3) development of work algorithms for each of the departments and the enterprise as a whole;

4) formation of requirements for developing a computer program;

5) programming the process of the enterprise;

6) test run and debugging of the developed program;

7) purchase and adjustment of the necessary equipment;

8) the use of a virtual enterprise in the educational process;

9) adjusting the algorithm of the virtual enterprise and the PC program based on the results of using this business game in the educational process (if necessary).

At the moment, we have implemented the first stage as shown in the article and moving on to the implementation of the second stage.

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