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Modern training courses increasing awareness of environmental protection

Nowoczesne szkolenia podnoszące świadomość ochrony środowiska

***Abstract**. This paper addresses the increasing global emphasis on environmental protection across various sectors, particularly in education related to electrical engineering, electronics, mechatronics, and automation. It highlights the need for retraining individuals transitioning from the mining industry to high-tech sectors that focus on environmentally sustainable technologies. The paper discusses an international initiative under the Erasmus+ Strategic Partnership program to develop a platform for such retraining courses. Key project goals, outcomes, and the broader impact of this educational initiative on environmental awareness are also explored.*

***Streszczenie.** Niniejszy artykuł porusza rosnące globalne znaczenie ochrony środowiska w różnych sektorach, szczególnie w edukacji związanej z inżynierią elektryczną, elektroniką, mechatroniką i automatyką. Podkreśla potrzebę przekwalifikowania osób przechodzących z przemysłu ciężkiego do sektorów zaawansowanych technologicznie, które koncentrują się na zrównoważonych ekologicznie technologiach. Artykuł omawia międzynarodową inicjatywę Partnerstwa Strategicznego w ramach programu Erasmus+, której celem jest stworzenie platformy kursów przekwalifikowujących dla takich osób. Przedstawione są kluczowe cele i rezultaty projektu, a także szerszy wpływ tej inicjatywy edukacyjnej na świadomość ekologiczną.*

Keywords: environmental protection awareness, retraining courses, engineering education, high-tech industry.
Słowa kluczowe: świadomość ochrony środowiska, kursy przekwalifikujące, edukacja inżynierska, przemysł zaawansowanych technologii.

Introduction

The European Union directives and regulations assume that by the year 2030, there will be a reduction in greenhouse gas emissions by at least 55%, compared to 1990, and at least 32% share of renewable sources in final energy consumption. [1] This means that during the next decade, there will be a significant change in the workforce distribution between different industrial sectors, particularly in electrical engineering, electronics, mechatronics, and automation, due to the enforced necessity of decreasing the production and use of fossil fuels. It is a huge challenge for the industrial sectors in the regions where fossil fuel mining, production, and usage have been the most significant and most resource-consuming industrial fields.

Estonian Ida-Virumaa County has historically been where oil shale is mined, processed, and used for fuel in electrical power plants, generating energy for the country. Additionally, oil shale is the resource used to produce shale oil as fuel in ships and heavy industry. Due to EU policies, these fossil fuel industries are destined to decrease, meaning that many workforces will lose their traditional jobs and must be transitioned to other industrial sectors. Around 80% of oil shale used globally is extracted and used in Estonia [2].

The Silesian region of Poland has always been the heart of the Polish coal mining industry. For historical reasons and because of Poland's available natural resources, the country's energy industry is primarily based on coal. This fuel's share of energy generated in 2020 was nearly 70% [3]. Like the situation in Estonia, the mining and coal processing industry will decrease in size, meaning that many coal mining industry workers must find their place in other fields. Estimates included in "Poland's Energy Policy until 2040" say that by 2040, the transition capacity of the fossil fuel-related workforce to other industry sectors will create up to 300,000 jobs [4].

According to Saima et al. [5], replacing the fossil fuel industry in the targeted areas and a large-scale industrial transition to a modern production industry are foreseen. This means that traditional industrial sectors and assemblies will be replaced by the industrial sectors and factories, which are robotized, automated, and energy efficient but still need a significantly qualified workforce. Such industries need a workforce qualified not only in a narrow field of engineering or production but also in a broader field of modern industrial ideology, focusing on system and novel technology integration into production. The same ideology must be considered for the operators and maintenance workers of such modern industry, combining different engineering fields into a combination of skills and knowledge, further regarded as mechatronics.

Considering the relatively low automation and robotization of the traditional fossil fuels industry, significant retraining is necessary for the workforce to transition to modern technological and industrial sectors. This has to be done so that the potentially available workforce can meet the needs and requirements of the contemporary mechatronics-oriented industry, which actively implements the Industry 4.0 ideology. The project proposes retraining courses for the soon-to-be-available workforce to meet those requirements. The topics covered by the retraining are electrical drives, automation, robotics, power electronics, and condition monitoring of industrial systems. These separate fields are strongly interconnected and overlapping, and together with the connection point of IT technologies, they can be considered the main technological pillars of the modern mechatronics-oriented industry.

This paper outlines the REMAKER [Retraining of Fossil Fuel Mining Area Workforce for Modern Industry (REMAKER) project webpage, taltech.ee/en/remaker] project's key goals and outcomes and discusses the training process's impact on enhancing understanding of environmental protection. Moreover, the project result related to the electrical drive module is described in detail.

Target groups

Modern industry needs broad knowledge specialists who can understand the aspects of different interconnected engineering areas [6]. As already mentioned, the common concept of contemporary industry is factories that are automated and robotized, with an emphasis on mechatronics. Due to the high level of digitalization and complex systems, broad knowledge and skills are needed instead of traditionally narrow expertise.

If one looks at a random factory involving a higher level of robotics, it can be found that different assemblies and concepts can be used for production. Still, the robots themselves cannot be considered without accounting for automation, as the robots, their tasks, and performance must be controlled and monitored [7]. This is done using electrical drives and automation technologies. One robot incorporates several electric drives, compiling together a whole drive system; hence, understanding modern control technologies, electrical drive designs, and automation methods is of utmost importance for the reliable and efficient usage of robots in the production industry.

Furthermore, these electric drives or drive systems need electricity to be functional. Yet, they cannot be directly connected to the supply grid. Power electronics and converters, using power electronics, are used as the essential link between electric drives and the electric grid. To ensure production quality, energy efficiency, and safety of people and assets, all the industrial systems must be condition monitored to react on time to any potentially harmful declinations from normality. To ensure this, five areas of retraining have been chosen – electrical drives, automation, robotics, power electronics, and condition monitoring of industrial systems. Combining them can create a module of mechatronics for industrial systems.

Estonian Qualifications Authority (OSKA) [8] has analyzed the needs for labor and skills necessary for Estonia's economic development over the next ten years. Its study on the manufacturing industry gives a comprehensive overview of the sector's need for labor force and skills. The analysis covers all the main fields of manufacturing – manufacturing of metal products, machinery, and equipment, as well as industries of electronics, timber, printing, apparel, textile, and food, all in the interest of the REMAKER project. Some of the key findings are as follows:

- The demand for industry and production engineers is growing due to digitalization, automation, and material technology development.
- Demand for mechatronics and technicians will increase in the next ten years, but employment can only be increased if a skilled labor force is available.
- The manufacturing industry lacks 2/3 of engineers, and the number of accepted students to manufacturing and processing programs has dropped by half and to engineering, manufacturing, and construction programs by a quarter in the last six years.
- There is an increasing need for specialists who know about managing and setting up automatic control systems, data analysis and interpretation, robots, and operating automated devices and robots.
- Employees who know the technology of materials and high-technology equipment are wanted.
- Some positions that require higher education are filled with employees with lower education levels, and the positions of retiring employees with general education should be filled with new workers, ideally specialists with a degree in higher education.

Considering the changes in industry in Europe as a whole, these findings can be scaled to all EU countries. The industry's lack of workforce can be partially covered by labor retraining, which is made available with the decrease in fossil fuel industries.

Project structure

The REMAKER project is being carried out by an international team of four universities from Estonia (Tallinn University of Technology, TalTech), Poland (Silesian University of Technology, SUT), Germany (University of Applied Science Mittelhessen, THM), and the Czech Republic (University of West Bohemia, UWB). The initiative aims to provide an educational platform for self-learning, primarily targeting workers from mining industries in Estonia (oil shale industry) and Poland (mining industry). The project is implemented within the Erasmus+ Strategic Partnership (KA2) framework for the higher education sector. Two main activities were undertaken: developing the educational platform and a series of study visits to modern industry factories and enterprises in Germany and the Czech Republic. The project aims to promote high-efficiency, cost-effective technological solutions that minimize energy and resource consumption, benefiting the natural environment.

Project outcomes

The project has yielded several significant outcomes. Firstly, it developed a comprehensive training platform featuring five detailed modules: Electrical Drives, Automation, Power Electronics, Robotics, and Condition Monitoring of Industrial Systems. The platform layout is shown in Fig.1. Each module comprises 6 to 8 lessons, incorporating instructional videos, training materials, and quizzes to ensure a deep understanding of the subject matter. Upon completing all lessons within a module, trainees receive a certificate that formally acknowledges their achievement.

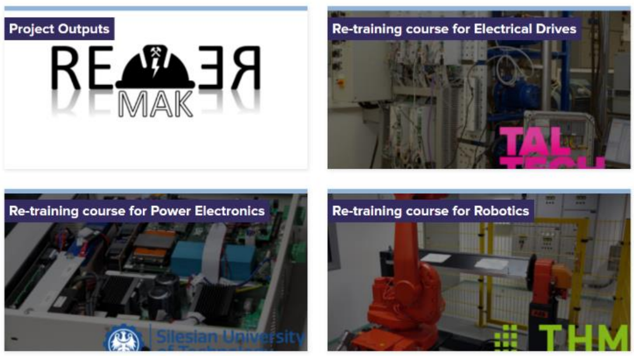

Fig. 1. REMAKER training course page with modules

The platform offers a flexible, user-friendly tool for self-directed learning. It provides open access to individuals interested in advancing their knowledge in key areas related to modern industry technologies and environmental sustainability. Each participating university contributed unique elements to the curriculum. TalTech introduced modern concepts, THM emphasized practical integration of mechanical systems, UWB focused on digital signal processing and advanced drive systems, and SUT included simulations and pulse width modulation techniques.

Additionally, the project identified common and specialized electrical drive topics across different institutions. Foundational concepts such as DC and AC drives were universally covered, while specialized topics included brushless DC motors and synchronous machine models. The project also highlighted the importance of promoting high-efficiency and low-cost technological solutions that minimize energy and resource consumption, thus supporting environmentally friendly practices in modern industry.

These outcomes collectively contribute to a robust educational framework, equipping workers transitioning from mining to high-tech sectors with the skills and knowledge needed for success in modern, sustainable industries.

Comparison between universities of the teaching of Electrical Drives in Bachelor study program

The courses are compared in two parts. The first examines the differences in workload across courses, measured in hours per semester, as shown in Fig.2, while the second identifies shared and unique topics in electrical drives courses among universities, as shown in Fig.3.

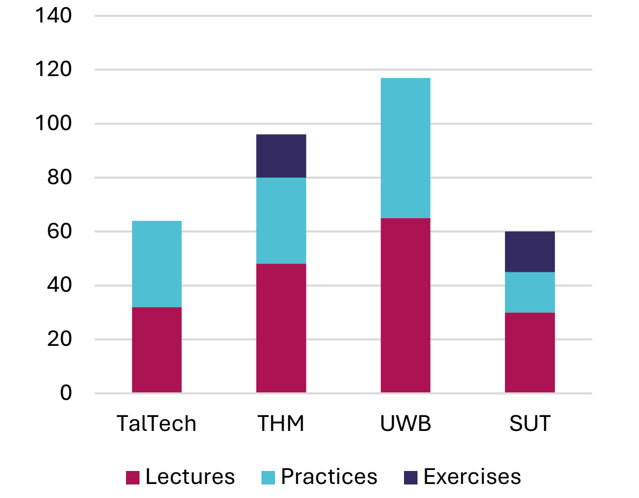

Fig. 2. Hourly allocation for electrical drives in bachelor's study programs across partner universities

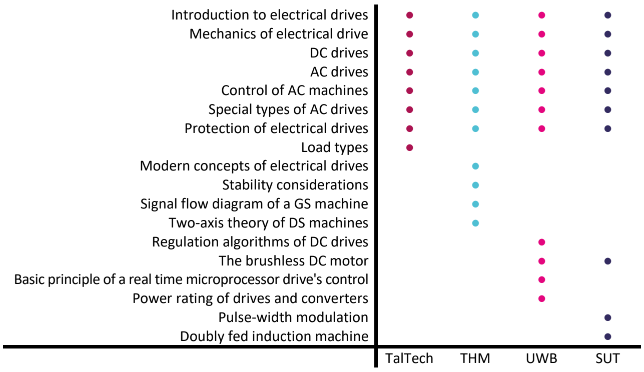

Fig. 3. Core topics of electrical drives in bachelor's study programs across partner universities

The data reveals that UWB has more study hours than SUT, with THM and SUT being the only institutions that allocate hours specifically for exercises. Although TalTech and SUT have similar lecture hours, UWB's lecture hours are double those of the other institutions. The study hours allocated to practical exercises are consistent across universities, influenced by UWB offering two courses in electrical drives for undergraduate students. The European Credit Transfer and Accumulation System (ECTS) credits are nearly identical across universities, averaging 6.5.

From the comparison of topics, several conclusions can be drawn:

1. Common topics across universities include an introduction to electrical drives, mechanics of electrical drives, DC drives, AC drives, control of AC machines, special types of AC drives, and the protection of electrical drives.
2. TalTech offers additional coverage on various technical load types.
3. THM includes modern concepts of electrical drives, stability considerations, signal flow diagrams for GS machines, and two-axis theory for DS machines.
4. UWB provides additional instruction on regulation algorithms for DC drives, the basic principles of real-time microprocessor drive control, and the power ratings of drives and converters.
5. SUT covers additional topics such as pulse-width modulation and doubly fed induction machines.
6. A common topic between UWB and SUT is the brushless DC motor.

This comparative analysis highlights the shared foundations and unique elements of each university's electrical drives curriculum.

Comparison between universities of the teaching of Electrical Drives in Master study program

The comparison of workload (Fig.4) and topics (Fig.5) across various universities highlights several key insights into the curriculum of electrical drives education. At the core, there are several fundamental topics that all institutions consistently cover. These include an introduction to electrical drives, which lays the groundwork for understanding these systems' basic principles and applications. Furthermore, vector models of AC electrical machines are explored, providing students with a deep understanding of how electrical machines function in a dynamic environment. This is complemented by the study of transforming vector variables, a critical concept that allows for the effective analysis and control of electrical drives.

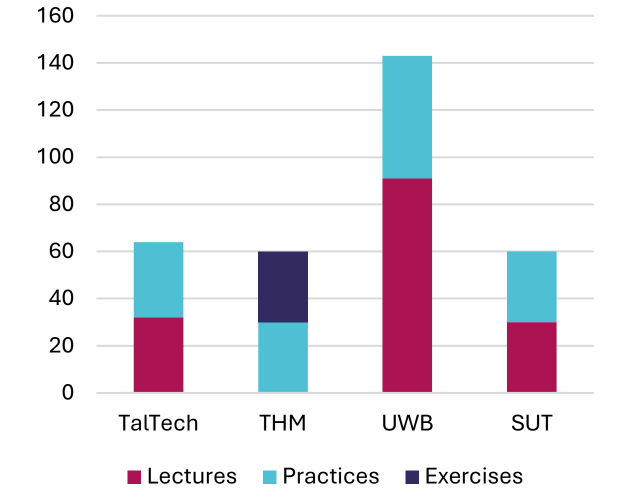

Fig. 4. Hourly allocation for electrical drives in master study programs across partner universities

Motor parameter estimation is another common topic, equipping students with the skills necessary to assess and optimize motor performance accurately. Building on this, universities delve into vector control principles of motors, which are essential for achieving precise control in AC motors. The curriculum also covers model predictive control of electrical drives, an advanced technique that enhances the efficiency and responsiveness of drive systems. Advanced control strategies are also explored, preparing students to tackle complex challenges in modern electrical drives. Finally, the discussion of trends and future developments in electrical drives ensures that students are well-versed in the latest innovations and are prepared for future advancements in the field.

Beyond these shared topics, each university brings its unique strengths to the curriculum. TalTech, for instance, supplements the core content with teachings on modern concepts in electrical drives and sensorless control techniques. These additions are particularly relevant in the context of evolving industry demands for more efficient and adaptable drive systems. THM distinguishes itself by offering master's students additional exercises and practical training related to the mechanical components and systems within electrical drives. This hands-on approach ensures that students gain practical experience in integrating mechanical and electrical elements, which is crucial for designing and operating complex drive systems.

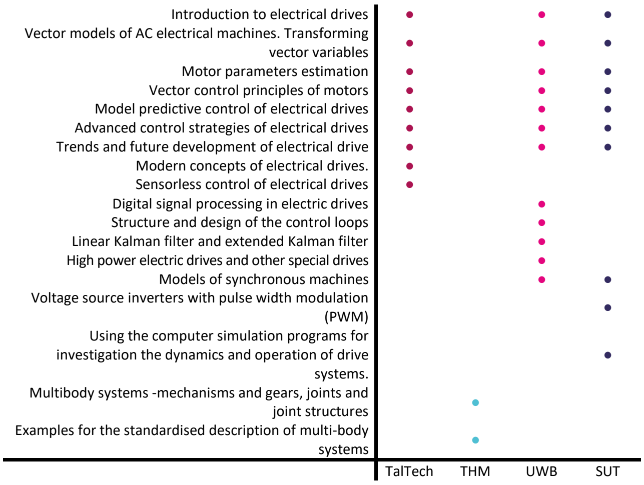

Fig. 5. Core topics of electrical drives in master study programs across universities

UWB's curriculum is further enriched with specialized courses on digital signal processing in electric drives, a critical skill for managing the complex signals involved in modern drive systems. Additionally, UWB covers the structure and design of control loops, providing students with a deep understanding of how to implement effective control strategies. Including linear and extended Kalman filters enhances students' ability to deal with noise and uncertainties in system measurements. UWB also strongly emphasizes high-power electric drives and other specialized drive systems, addressing the needs of industries that require robust and powerful solutions.

On the other hand, SUT focuses on voltage source inverters with pulse width modulation (PWM), a fundamental technology for controlling the power and speed of electric drives. Using computer simulation programs at SUT allows students to investigate the dynamics and operation of drive systems in a controlled, virtual environment, providing invaluable insights into real-world performance. Additionally, a noteworthy overlap exists between UWB and SUT, where both universities cover models of synchronous machines. This commonality underscores the importance of these models in the broader field of electrical drives, reflecting their widespread application in various industrial and technological contexts.

In conclusion, while the core topics of electrical drives are universally addressed, each university enhances its curriculum with specialized content that reflects its unique expertise and focus areas. This diverse approach ensures that students receive a comprehensive education, equipping them with both foundational knowledge and advanced skills tailored to meet the demands of modern electrical drive systems.

Curricula for re-training course for electrical drives

The new curriculum for the retraining course in electric drives is designed to provide students with a comprehensive understanding of these systems' construction, operation, and application in industrial and infrastructural environments. The program aims to equip students with the knowledge and skills to effectively select, control, and protect electric drives, ensuring their seamless integration into modern industrial systems.

The course begins with an introduction to the fundamentals of electric drives, including a historical overview of their development. Students are introduced to the key components and operating principles of electric drives, with a strong emphasis on understanding the energy exchange processes between the power supply, the electric drive, and the load machine. This foundational knowledge is crucial for selecting the appropriate drive based on specific load and operating conditions, including speed and torque control considerations. Most of the course focuses on studying energy flows within electric drives, encompassing power and control circuits. Students will learn about the mechanical aspects of drives, such as transmissions, basic movement equations, and the translation of moments of inertia, forces, torques, and speeds. This section includes practical examples and calculations related to load types, standardized duty types, and motor power selection, enabling students to make informed decisions when choosing drives for various applications.

The curriculum also covers the characteristics and control methods of both DC and AC drives. For DC drives, topics include rheostat control, power converter integration, and pulse control techniques. The course further explores the electromechanical characteristics of AC asynchronous drives, including starting methods, soft starters, and frequency control principles. Students will investigate energy flows in frequency-controlled drives and the application of frequency converters with different loads. Advanced topics, such as synchronous and servo drives and stepper motor drives, are also included. Students will gain a deep understanding of advanced control strategies for electric drives, including the fundamentals of vector control and direct torque control. These techniques are essential for modern electric drives' precise and efficient operation, particularly in complex industrial environments. The curriculum also addresses contemporary challenges in electric drives and the dynamics of AC electrical drives, preparing students to address real-world issues in the field.

The course includes comprehensive training on the protection and control of electric drives, focusing on selecting the appropriate protective devices based on specific applications. Students will learn about the various sensors used in drive systems, which are critical for monitoring and controlling drive performance. Additionally, the curriculum familiarizes students with the user interfaces of modern microprocessor-controlled drives, providing them with the skills needed to interact effectively with these systems. Beyond the technical aspects of electric drives, the course also covers production technologies and industrial systems, including the hardware and software resources used in industrial automation, such as pneumatic systems, drives, controllers, SCADA systems, and servers. Students will learn about industrial data communication, relevant standards, and standardized programming languages (IEC 61131-3, IEC 61499, DIN 66312) used for industrial controllers and robots, equipping them with the skills to program and manage these systems effectively.

The course concludes with a focus on electromagnetic compatibility in electric drives, ensuring that students understand the importance of minimizing electromagnetic interference in drive systems. Additionally, students will explore the application of electric drives in various fields, including electric transportation, providing a broad perspective on the potential uses of electric drives in modern technology. By the end of the course, students will have acquired a thorough understanding of energy exchange processes in electric drives, knowledge of different drive types and their control possibilities, and the ability to select and protect appropriate drives based on application requirements. They will also gain familiarity with industrial production technologies, standardized programming languages, and contemporary issues in electric drives, preparing them to meet the demands of modern industry and contribute to the development of sustainable and efficient drive systems.

Conclusion

Based on the provided outputs, several core topics are commonly addressed among universities in the field of electrical drives. These include introductory concepts, mechanics, DC drives, AC drives, control of AC machines, specialized AC drives, and the protection of electrical drives. These foundational topics ensure that students comprehensively understand electrical drives across different institutions.

However, each university also contributes unique elements to the curriculum, focusing on specific aspects of electrical drives. TalTech incorporates modern concepts of electrical drives and sensorless control, equipping students with the latest knowledge.

UWB enhances its curriculum with instruction on digital signal processing in electric drives, control loop structures, and designs, as well as using Kalman filters in drive systems. UWB also addresses high-power and specialized electric drives, catering to the needs of these advanced systems. SUT includes teachings on voltage source inverters with pulse width modulation (PWM) and employs computer simulations to investigate the dynamics and performance of drive systems, providing students with hands-on experience and insights. Moreover, there are common topics between UWB and SUT, such as brushless DC motors and synchronous machine models, underscoring the relevance and application of these technologies in electrical drives.

In summary, while foundational topics are consistently covered across universities, each institution enriches its curriculum with additional specialized teachings. This approach ensures that students receive a well-rounded education, integrating fundamental principles and advanced knowledge, preparing them for various challenges and innovations in electrical drives.

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