Interactive Course for Power Plant Compliance Tests With Grid Connection Requirements

Lidija M. Korunović, University of Niš, Serbia
Vojkan Kostić, University of Niš, Serbia
Tomislav Baškarad, University of Zagreb, Croatia
Igor Kuzle, University of Zagreb, Croatia

The Paris Conference on Education 2025
Official Conference Proceedings

Abstract

In today's power systems, more and more often than in recent decades, new power plants mostly based on the application of renewable energy sources, are being built. That is why it is important to study grid connection requirements of the power plants and corresponding compliance tests within the educational subjects of electrical engineering studies. Also, facility owners must know precisely the requirements related to the compliance tests that should ultimately lead to the operational notification of the plant. The interactive course presented in the paper can be used by industry and the academic community. It was created within the TRANSIT project funded by the European Union and is part of a comprehensive interactive web platform for education in the field of renewable energy sources and sustainability. The interactive course on power plant compliance tests with grid connection requirements is developed on the OpenEdx platform and consists of three components: a PowerPoint presentation serving as the theoretical basis of the topic, an interactive demonstration allowing users to identify the requirements their facility must meet, based on the voltage level at the connection point and maximum capacity of power-generating module, and a quiz to the material covered. The course is followed by a survey that provides feedback on the course. Learning the procedures for connecting the power plant to the grid and numerous requirements for compliance tests is greatly facilitated by the interactive course that significantly contributes to the development of competences of industry employees and other stakeholders.

Keywords: interactive course, power plant, grid connection, OpenEdx platform, renewable energy

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Introduction

In nowadays power systems, new power plants that use different electricity generation technologies are built more often than in the last decades (Breeze, 2019). Therefore, it is very important to know precisely the requirements related to the compliance tests that should finally lead to operational notification of a power plant issued by the relevant transmission system operator (TSO) ("Establishing a guideline," 2017). Firstly, the set of requirements for compliance tests provides the technical requirements for grid connection and points to the needed technical documentation. When technical documentation is prepared properly and the compliance tests are performed successfully, the final operational notification is issued by TSO.

The legal framework for compliance tests is the regulation ("Establishing a Network Code," 2016), abbreviated RfG, which full implementation in the European Union started on April 27, 2019. According to RfG power-generating modules are divided into groups with a pre-known set of requirements. The groups are formed in relation to electricity generation technology, and maximum capacity and the voltage level at the connection point.

The content of the interactive course presented in this paper is partly based on the study (Kostić et al., 2021). Subject of this study was the harmonization of the existing Distribution Network Code (Distribution System Operator, 2017) with RfG, in the part related to the compliance tests for power-generating modules. The aim of the study was to provide: the proposal of requirements for compliance tests for different types of power-generating modules, and the proposal of protocol for each specific compliance test.

The topic of interactive courses is highly significant for the industry. In modern power systems, new power plants are being constructed more frequently than in previous decades, often utilizing diverse technologies for electricity generation, with a strong emphasis on renewable energy sources (RES). All facility owners should be aware and very well informed in detail about requirements for compliance tests. For them these are of crucial importance from both technical and economic point of view, because the design and building of the power plant is not economically justified if plant operational notification will not be issued.

On the other hand, the students of electrical power engineering should study grid connection requirements and compliance tests that must be performed in modern power systems. Thus, this matter should be included in the curriculum of power engineering studies in terms of developing the competences of future experts.

The rest of the paper is structured as follows: next section explains how the interactive course was developed; following three sections describe the parts of the course — a PowerPoint presentation, an interactive demonstration, and a quiz based on the material covered, respectively; an overview of the questions included in the survey providing the feedback on the course is presented in penultimate section, while the main conclusions regarding the contribution of the interactive course to the development of skills and competences of students and industry employees are drawn in the last section.

Development of the Interactive Course

The interactive course presented in the paper was created within the TRANSIT project funded by the European Union (TRANSIT project, 2022) and is part of a comprehensive

interactive web platform for education in the field of RES and sustainability. For the development of interactive web platform different options were considered: Brilliant, Moodle and OpenEdx.

Brilliant platform (Brilliant) is famous for its visually engaging and interactive problem-solving approach, particularly in science, technology, engineering and mathematics (STEM) education. It is characterized by an intuitive learning experience through interactive visualizations and gamified content. However, its primary focus on specific topics, such as mathematics and computer science, limits its flexibility for broader educational applications. Additionally, Brilliant.org is not an open-source platform, making customization and course structure modifications more challenging.

Moodle platform (Moodle) is a widely used open-source learning management system that offers extensive customization options and many plugins for various functionalities. Its strengths lie in its robust community support, scalability, and flexibility for hosting diverse course types. However, Moodle's interface can feel outdated and less intuitive compared to modern platforms. Setting up and maintaining Moodle can also be very demanding.

OpenEdx platform (OpenEdx) was selected by TRANSIT project because it is an open-source platform that supports a wide range of course formats, including self-paced and instructor-led options. OpenEdx offers advanced analytics, robust scalability, and seamless integration with third-party tools and application programming interfaces (APIs). The platform is trusted by top organizations and universities worldwide, such as MIT and Harvard, which confirms its reliability. Additionally, OpenEdx provides a modern and professional interface, gamification options, and tools for creating highly interactive and engaging courses, making it the ideal choice for developing various educational courses.

Several interactive courses were developed by TRANSIT project on the OpenEdx platform. The OpenedX platform offers two main options tailored to different users: learners and course developers (teachers). For Learners OpenedX provides flexible and interactive learning experience. Learners can access a variety of courses, engage with multimedia content, participate in quizzes and discussions, and track their progress. The platform supports self-paced and instructor-led courses, allowing users to choose the learning style that best suits their needs.

Participants must enrol in each course individually in order to attend. For the participation in the course titled “Power Plant Compliance Tests with Grid Connection Requirements” only basic understanding of power systems and regulatory frameworks are required, as stated at the very beginning of the course.

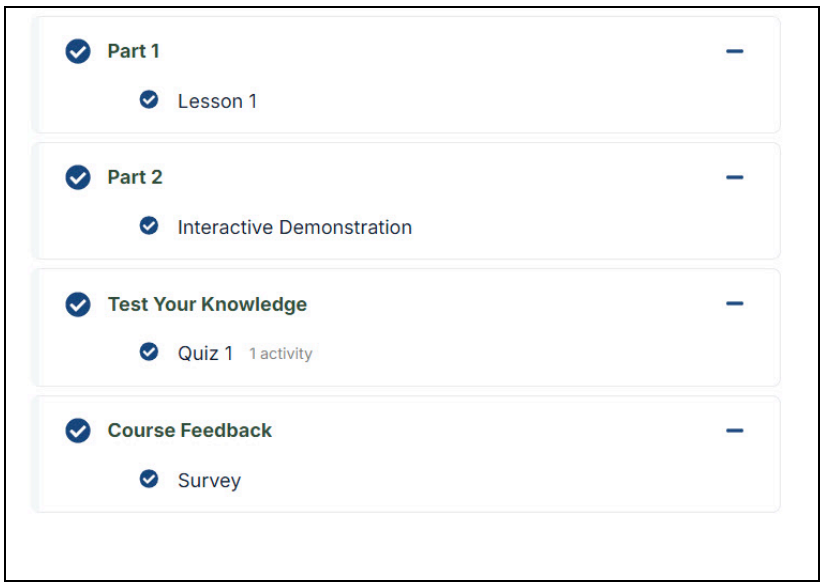
Figure 1 illustrates the content of the course “Power Plant Compliance Tests with Grid Connection Requirements.” This and all other courses combine theoretical content, interactive simulations, quizzes, and surveys to facilitate effective learning. The key features include:

- Theory Module – Presents educational material in the form of PowerPoint presentations, HTML text, or multimedia content.
- Interactive Simulations – Hands-on applets that allow users to manipulate variables and observe real-time effects.

- Quizzes and Assessments – A variety of question formats (multiple-choice, dropdown, text input) to evaluate learning progress.
- Surveys – User feedback forms to gather insights and improve course content.

These components are described individually in detail in the following sections.

Figure 1
The Course Content



PowerPoint Presentation

Introductory Parts

The PowerPoint presentation is the first part of the course and serves as the base for learning of power plant compliance tests with grid connection requirements. At the beginning of the presentation the importance of knowing the requirements of compliance tests is described and the procedure for connecting a power plant to the grid is outlined. As an important and unavoidable part of studied matter, the legal framework of compliance tests is referenced ("Establishing a guideline," 2017; "Establishing a Network Code," 2016). These documents form the basis of the course and allow participants to gain insights into the legal framework which regulates compliance tests within the European Union.

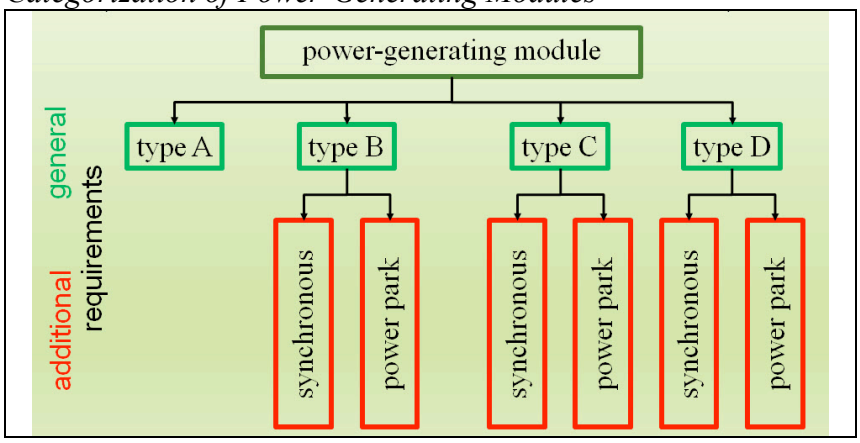
Categorization of Power-Generating Modules

Further, the presentation covers the categorization of power-generating modules based on electricity generation technology, maximum capacity, and connection point voltage ("Establishing a Network Code," 2016). According to this categorization, power-generating modules can be of type A, or type B, or type C, or type D (Figure 2) and each type has specific general requirements for compliance tests. In terms of types of applied electricity generation technologies, type B, type C and type D modules are divided to: synchronous power-generating modules (the frequency of the generated voltage and the frequency of network voltage are in synchronism) and power park modules (the module is non-synchronously connected to the network or connected through power electronics). Type B,

type C and type D modules also have their distinctive additional requirements for compliance tests depending on their electricity generation technologies.

Figure 2

Categorization of Power-Generating Modules



It is emphasized that power-generating modules can be only of type D for voltage levels greater or equal to 110 kV, while for voltage levels less than 110 kV the modules can be of type A, type B, type C and type D, depending on their maximum capacities. For small modules which maximum capacities are less than 0.8 kW, the categorization is not done and the compliance tests with grid connection requirements are not needed.

Different limits for maximum capacity thresholds in different synchronous areas according to ("Establishing a Network Code," 2016), i.e. RfG, are listed in the presentation. The maximum capacity thresholds that define power-generating modules as Type B, Type C, and Type D are identical for Continental Europe and Great Britain. These thresholds are set at 1 MW, 50 MW, and 75 MW, respectively. However, national maximum capacity thresholds are proposed by the relevant TSO and approved by the relevant regulatory authority or state. Therefore, national maximum capacity thresholds can be different, even in some EU states, as demonstrated in PowerPoint presentation.

Technical Requirements for Grid Connection

All technical requirements for grid connection across various module types are summarized in the presentation. Firstly, the general requirements for different types of power-generating modules are listed, followed by the additional requirements for modules of type B, of type C and of type D for both synchronous power-generating modules and power park modules.

The relation which describes approximately the relationships between "Set of requirements for compliance tests for power-generating modules of" (abbreviated "...") type A, type B, type C and type D is:

$$\ldots \text{ type A} \subset \ldots \text{ type B} \subset \ldots \text{ type C} \subset \ldots \text{ type D}. \quad (1)$$

It indicates that the list of requirements for power-generating modules of type A is the shortest, while the list of the requirements for the modules of type D is the longest one, and because of that it is the most difficult to fulfill all these requirements. As illustration, the set of requirements for the modules of type A consists of only seven requirements, while the set

of requirements for compliance tests of power park modules of type D encompasses even forty-two requirements that need to be fulfilled.

Procedure for Power Plant Connection to the Grid

The whole procedure for successful power plant connection to the grid can be summarized as follows:

- Technical requirements for grid connection of power-generating module are formed based on a set of requirements for compliance tests known in advance.
- Technical documentation is prepared.
- Power-generating module is constructed.
- Compliance tests are carried out.
- Operational notification is issued.

The PowerPoint presentation clarifies the last two steps of the procedure for power plant connection.

Carrying Out the Compliance Tests

Each compliance test can be carried out in one of the following three ways:

- by equipment certificate issued by an authorized certifier,
- by field testing (measurements),
- by testing on a simulation model (simulations),

at relevant system operator's decision, and in accordance with RfG and legal acts related to electrical network operation. For each compliance test, the relevant system operator is obliged to define precisely in advance the Procedure for compliance testing, to introduce the facility owner to this testing, but also to play significant role in the process of carrying out compliance tests, as explained in detail in the PowerPoint presentation. However, the facility owner is ultimately responsible for carrying out compliance tests.

Operational Notification

Operational notification of type A, type B, type C and type D power-generating modules is described in the presentation. The notification procedure of type A module is the simplest one and consists of two steps:

- Facility owner submits an installation document for each power-generating module within the power plant, to the relevant system operator. The installation document must contain equipment certificates issued by an authorized certifier.
- If everything is in order, operational notification will be issued to the facility owner and the plant can be connected to the grid.

Operational notification procedures for both type B and type C power-generating modules are the same, but more complex than operational notification of type A power-generating modules. The notification for type B (and type C) modules encompasses the submission of a power-generating module document (separate document for each power-generating module within the power plant), which must contain a statement of compliance.

At the request of the relevant system operator, the facility owner also shall provide equipment certificates issued by an authorized certifier, simulation models (mandatory for type C),

compliance test reports (for field testing and/or for testing on a simulation model), and studies demonstrating steady-state and dynamic performance. On acceptance of a complete and adequate power-generating module document, the relevant system operator shall issue a final operational notification to the facility owner.

The operational notification procedure for the connection of each new type D power-generating module is even more complicated than the procedures for the connection of type B and type C power-generating modules. It comprises:

- energization operational notification,
- interim operational notification, and
- final operational notification,

and all of them can be described by several items, as shown in PowerPoint presentation.

Furthermore, limited operational notification of type D power-generating modules can be issued to the facility owners in the case when facility owner reasonably expects the following circumstances will persist for more than three months: the facility is temporarily subject to either significant modification or loss of capability affecting its performance, or the failure of equipment leads to non-compliance with some relevant requirements.

Interactive Demonstration

Interactive demonstration is the second part of the course. It focuses on comprehensive and the most difficult parts of the PowerPoint presentation related to the categorization of power-generating modules and technical requirements for their grid connection.

As a reminder, the window of interactive section first provides an overview of:

- the legal framework for power plant compliance tests with grid connection requirements,
- the categorization of power-generating modules based on electricity generation technology, maximum capacity, and connection point voltage, and
- the limits for maximum capacity thresholds from which the power-generating modules are of type B, type C and type D in Continental Europe and Great Britain.

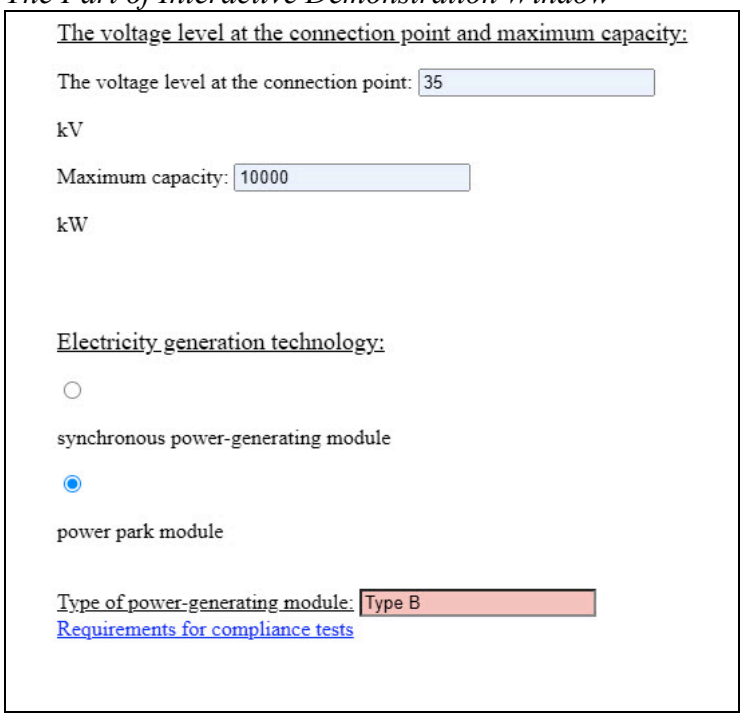
Afterwards, the interactive section allows participants to quickly identify the requirements their facility must meet, based on the voltage level at the connection point, maximum capacity of power-generating module and electricity generation technology (Figure 3). This part of the interactive demonstration is built using Hypertext Mark-up Language (HTML) and Cascading Style Sheets (CSS).

An example of the interactive demonstration is presented in Figure 3. The voltage of 35 kV and the maximum capacity of 10000 kW are inserted in the boxes intended to the voltage level at the connection point and the maximum capacity of the power-generating module, respectively. Power park module is chosen as the electricity generation technology, and “Type B” is obtained in the box intended for the type of power-generating module. At the bottom of the figure, the link “Requirements for compliance tests” leads to the set of requirements for compliance tests for type B power park module.

In a similar way, the participants of the course can train themselves and determine the knowledge related to the sets of requirements for different types of power-generating modules.

Figure 3

The Part of Interactive Demonstration Window



Quiz

The third part of the interactive course is a quiz, designed to assess participants' knowledge and understanding of the material. The quiz features more than ten questions in different formats, such as checkboxes, text inputs, multiple-choice options, and dropdown lists. In principle, the answers to the questions can be accompanied by further explanations relating to a specific answer.

The questions cover all parts of the studied matter, starting from the legal framework and categorization of power-generating modules, over the sets of requirements for compliance tests and whole procedure for power plant connection to the grid, to the carrying out the compliance tests and operational notification of power-generating modules.

The quizzes feature a variety of question formats, such as:

- Multiple-choice questions – Testing factual knowledge and conceptual understanding.
- Dropdown lists – Allowing users to select the most appropriate answer from a given set.
- Text input fields – Encouraging learners to formulate their own responses.

Additionally, some quiz questions are accompanied by explanations that clarify why certain answers are correct or incorrect, providing valuable feedback for deeper learning.

As illustration, Figures 4, 5 and 6 present the parts of the screenshots with only three short questions (due to space limitation) and their correct answers. The answer to Question 2

(Figure 4) is selected from the dropdown lists. Some questions, such as Question 4 (Figure 5) which is in a multiple-choice format, provide users with additional explanations and clarifications after the answer is selected. Thus, a further remark in relation to Question 4 (not represented in Figure 5 as it would be too small) reads: "For power plants of maximum capacity less than 0.8 kW compliance tests with grid connection requirements are not needed."

Question 10 (Figure 6) refers to carrying out compliance tests. The correct answer in this figure is selected from dropdown lists with three offered answers: Relevant system operator, Facility owner, Relevant regulatory authority.

Figure 4

Question 2 With the Selected Correct Answer

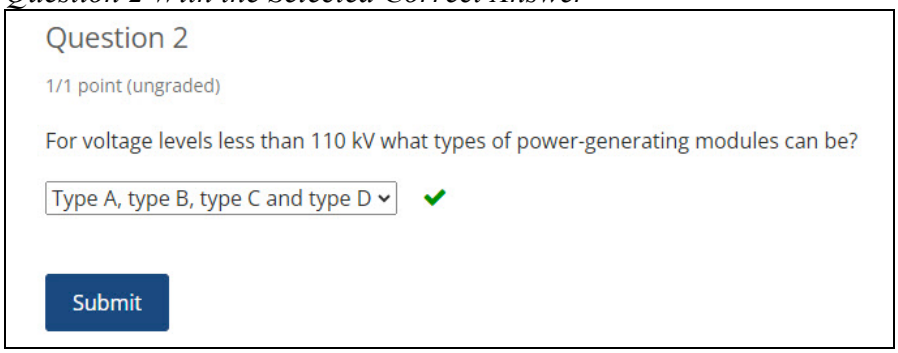


Figure 5

Part of the Screenshot With Question 4 and Its Selected Answer

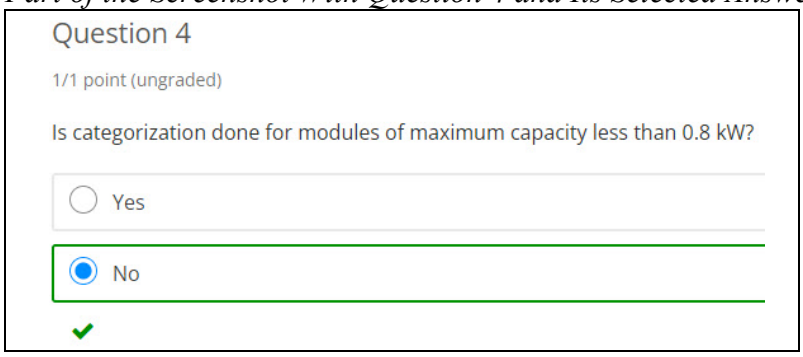
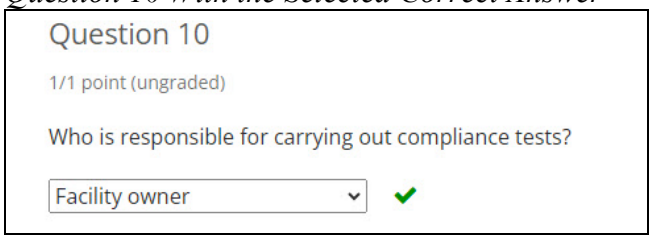


Figure 6

Question 10 With the Selected Correct Answer



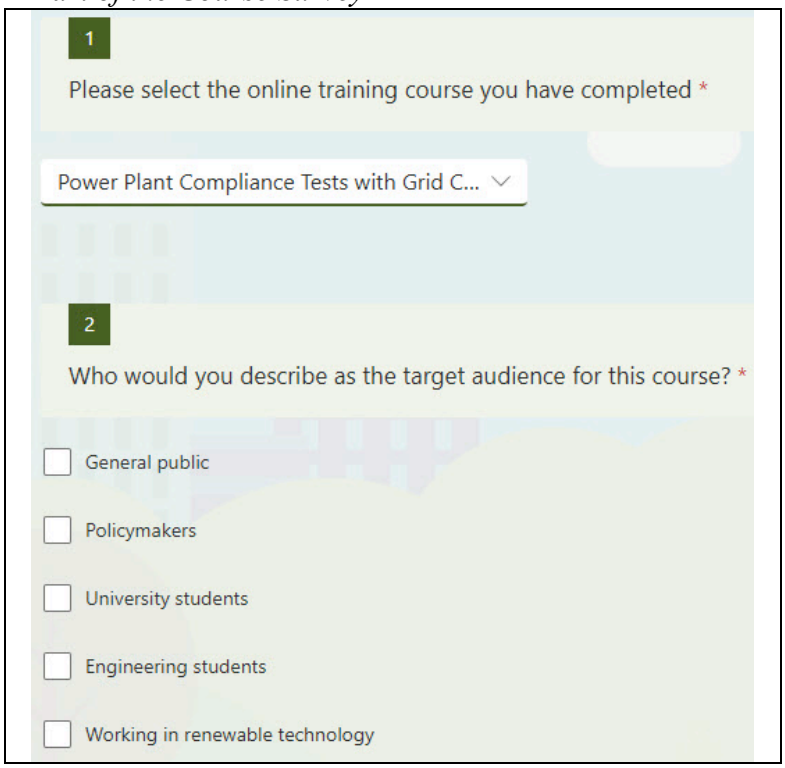
Course Feedback

The final part of the course is a survey that provides feedback on the course and helps the authors to improve the quality of the interactive course. This course survey, created using Microsoft Forms, allowed participants to reflect on their learning experience and offer

suggestions for improvement. The survey combined quantitative and qualitative elements to provide a comprehensive overview of user satisfaction, course design effectiveness, and areas for further development.

The survey included a mix of closed-ended and open-ended questions, each designed to capture specific aspects of the learning experience. Some questions (Figure 7) aimed to identify the target audience, such as their familiarity with the topic or the specific course they attended. Others focused on evaluating the educational impact, including whether the course met participants' learning expectations, the clarity and ease of understanding, and overall satisfaction. At the end, open comment fields allowed participants to suggest improvements or highlight particularly effective features.

Figure 7
A Part of the Course Survey



Among the nine offered modules, the feedback from the course titled "Power Plant Compliance Tests with Grid Connection Requirements" indicated a high level of engagement and satisfaction. Participants rated the course positively, with average satisfaction and expectation scores consistent with the overall dataset. All respondents found the course content relevant and timely, particularly in the context of increasing integration of renewable energy sources into power systems and the evolving regulatory framework within the EU. Notably, several participants emphasized the value of the interactive simulations and visualizations used to demonstrate compliance procedures.

The course was also praised for its clear structure and the way it connected theory with standards and regulations (e.g., European Network of Transmission System Operators for Electricity (ENTSO-E) grid code and national grid codes). Several participants mentioned that the course would be particularly beneficial for engineers working in commissioning, compliance testing, or regulatory bodies, confirming that the course successfully reached its intended audience.

Based on this feedback, future iterations of the course may include:

- Video walkthroughs of compliance test procedures.
- Interactive checklists or flowcharts summarizing test sequences.
- Optional advanced sections for users already familiar with regulatory compliance.

Finally, the results suggest that the course successfully addressed a real need for practical, standards-based training in an increasingly regulated energy environment.

Conclusion

The interactive course presented in the paper is designed to simplify the learning process for participants tackling the extensive material related to power plant compliance tests with grid connection requirements. The course begins with a detailed PowerPoint presentation, followed by an interactive demonstration to enhance practical understanding. Participants then assess their knowledge through a quiz and contribute to course improvement by providing feedback through a survey. The importance of course topic is great because many new power plants are planned to be built and connected to the grid across Europe, mostly using low-carbon technologies and contributing to a sustainable future for the planet.

The course effectively fulfilled its educational objectives by providing a clear, interactive, and application-oriented overview of compliance procedures. The use of theory presentations and visual tools was particularly appreciated by participants, helping to bridge the gap between theoretical standards and real-world implementation. Feedback suggests that the course meets a growing need for accessible, regulation-focused training in the evolving energy sector.

Finally, facility owners can also use the course as a step-by-step guide how to obtain operational notification of their new power plants, while TSOs can apply it as a reminder of the sets of requirements for compliance tests for different types of power-generating modules.

Acknowledgements

This paper represents a part of the research conducted within the Project TRANSIT funded by the European Union on the basis of Grant Agreement No. 101075747. The paper is also funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia based on the Contract on the Implementation and Financing of Scientific Research NIO in 2024, registration number 451-03-66/2024-03/200102 from 05.02.2024.

References

Breeze, P. (2019). *Power Generation Technologies*. ELSEVIER LTD.

Brilliant [Computer software]. Brilliant.

Distribution System Operator. (2017). *Distribution Network Code of EPS Distribucija d.o.o.* EPS.

Establishing a guideline on electricity transmission system operation. (2017, August). *Official Journal of the European Union*. http://data.europa.eu/eli/reg/2017/1485/oj

Establishing a Network Code on Requirements for Grid Connection of Generators. (2016, April). *Official Journal of the European Union.* http://data.europa.eu/eli/reg/2016/631/oj

Kostić, V., Radić, M., Stanković, S., Rašić, M., Trojić, B., Lazić, V., Ilić, U., Manasijević, Z., Radović, G., & Dabić, J. (2021). Predlog Protokola za ispitivanje usaglašenosti elektrane sa tehničkim uslovima za priključenje na distributivni sistem električne energije [Proposal of Compliance Tests Protocols for Power Generation Plant With Technical Requirements for Its Connection to Distribution System]. Niš: University of Niš – Faculty of Electronic Engineering.

Moodle [Computer software]. Moodle.

OpenEdx [Computer software]. OpenEdx.

TRANSIT project. (2022). *Transition to a sustainable future through training and education*. https://transitproject.eu

Contact email: lidija.korunovic@elfak.ni.ac.rs