Manual

for
teachers

installing and maintaining electrical equipment in wind farms

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Contents

1. INTRODUCTION 4
1.1. Purpose of the manual 4
1.2. Significance and application of wind energy 7
1.3. Structure of the manual 8
2. RENEWABLE ENERGY SOURCES 9
3. SAFETY AT WORK AND PROTECTION OF THE ENVIRONMENT 14
3.1. Possible hazards to the health and safety of workers when working on wind farms 14
3.2. Application of safety and protection measures at work during the performance of works on wind power plants 15
3.3. Implementation of safety measures and personal protection measures when working at height in wind power plants 16
3.4. Implementation of measures to reduce the negative impact of wind power plants on the environment 19
4. WIND ENERGY 22
4.1. Basic applications of wind energy 22
4.2. Characteristics of wind farms 23
5. INSTALLATION AND DISASSEMBLY OF ELECTRICAL EQUIPMENT IN WIND POWER PLANTS 33
5.1. Preparation of the terrain for the installation of power equipment in wind farms 33
5.2. Assembling and disassembling the assembly structure of equipment in wind power plants 34
5.3. Assembly/disassembly and connection of power equipment in wind power plants 37
5.4. Selection of protective equipment and equipment for assembly and disassembly of wind farm elements 41
6. PERFORMANCE OF ELECTRICAL INSTALLATIONS OF WIND POWER PLANTS 44
6.1. Types and basic elements of electrical installations of wind farms 44
6.2. Installation of cable structures and laying of electrical installation cables 45
6.3. Installation of switchboards and control panels 46
6.4. Connection of electrical installation elements in distribution and control panels, cabinets and counters 47
6.5. Installation of grounding and lightning protection of wind power plants 48
6.6. Measurement and control of the performance of wind turbine components 49
7. EQUIPMENT MAINTENANCE AND MONITORING IN WIND POWER PLANTS 50
7.1. Types of maintenance and activities in the maintenance of wind power plants 50
7.2. Preventive maintenance works of wind power plant elements 50
7.3. Corrective maintenance works of wind power plant elements 52
7.4. Maintenance works of electrical installations of wind power plants 54
7.5. Collection, processing and storage of data in wind power plants 58
8. CONCLUSION AND RECOMMENDATIONS 59
9. MATERIAL CONDITIONS AND EQUIPMENT 61
Literature and used sources 63
Organizations and standardization sources: 64
Links to suggested video material 64

1. INTRODUCTION

1.1. Purpose of the manual

This manual was written as part of the Renewable Energy Services in Education and Training RESET project, which is implemented by the Education Reform Initiative of South Eastern Europe (ERI SEE) Secretariat in cooperation with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), and is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ). The manual was designed to support high school teachers and adult education program lecturers who teach in the field of renewable energy sources. The manual can be used by relevant ministries and educational agencies, companies involved in practical education, training centers, private institutions working in the field of renewable energy, practical education instructors, and other interested parties.

Its purpose is to provide clear methodological guidelines, practical recommendations and didactic strategies for the effective implementation of the teaching process. The manual follows the content of the manual for students/attendees "Installation and maintenance of electrical power equipment in wind farms", expanding it with teaching explanations and guidelines for conducting lessons.

The material was agreed among experts in the field of renewable sources of electricity and education from six economies: Albania, Bosnia and Herzegovina, Montenegro, Kosovo*[1], North Macedonia and Serbia, involved in the implementation of the project."

Considering the global trend of switching to renewable energy sources, this manual contributes to the training of teachers for quality preparation of students/students in one of the most promising areas of power engineering. The course program covers key topics in the field of installation, maintenance and safety measures in wind farms, and teachers play a key role in imparting the knowledge and skills necessary to work in this industry.

Objectives of the manual

This handbook enables teachers to:

- A structured approach to teaching, with a combination of theoretical explanations and practical exercises.
- Developing methodological strategies for the active involvement of students/participants in the teaching process.
- Guidelines for evaluating knowledge and monitoring student/participant progress through practical tasks.
- Practical examples and scenarios for the execution of teaching units that enable easier mastering of the teaching material.

Guidelines for teachers

Teachers have a key role in the implementation of the teaching process, and this manual enables them to:

- A clearly structured approach to student/participant training.
- Connecting theoretical foundations with practical exercises.
- Application of modern teaching methods to increase student/participant engagement.
- Organization of individual and team tasks in order to simulate real working conditions.

[1] *This name is without prejudice to the status and is in accordance with the Resolution of the Security Council of the United Nations 1244/1999 and the Opinion of the International Court of Justice on the Declaration of Independence of Kosovo.*

Recommendations for teaching

- **Introduction to the topic**- Start with constructive theoretical lectures on the given topic. Theoretical classes are held in a classroom equipped with modern technical support for the realization of lectures, with the use of presentations, simulations and continuous communication with students/participants. The theoretical part of the class should be based on presentations, the use of demonstrative means for demonstration, as well as simulations, in order to motivate all students/participants to actively follow the class. Through questions, suggestions and exchange of opinions on topics, students/participants will additionally contribute to the development of their own professional abilities and improvement of teamwork.
- **Discussion and analysis**- Organize debates and discussions with students/participants on a given topic.
- **Practical exercises**- Enable students/participants to become familiar with the tools, equipment and devices needed for the implementation of practical exercises, through demonstrations and simulations. Practical teaching is carried out in small groups, in order to reduce the disruption of the work process and enable the active involvement of each student/participant in practical work. Part of the practical training is conducted in the laboratory/center for tests and measurements, which are equipped with recommended material resources and provide conditions for the safe work of participants, while part of the practical training is conducted in cooperation with local companies that build and maintain wind farms.
- Practical exercises/tasks can be done individually, in pairs or small groups, but the method of work must be organized so that each student/participant does the assigned practical exercises/tasks independently. For each practical exercise, each student/participant prepares an individual report, which contains a description of the work, results and conclusion. Through these exercises, students/participants are trained to perform real tasks in the field, while respecting safety measures at work.
- It is recommended that certain practical exercises be carried out through visits to energy facilities of renewable energy sources, laboratories for testing and measurements or at the employer, where students/participants can gain practical experience in real working conditions. This approach enables direct application of theoretical knowledge, familiarization with modern technologies and work in a professional environment. The visits are group, but each student/participant should independently prepare a report on the implementation of the practical exercise.
- **Exercises: Research papers and preparation of seminar papers/PPT presentations**- Research papers encourage analytical thinking and the development of technical skills. Students/Participants should be directed to select a relevant topic, collect data from reliable sources and analyze the collected information. Term papers and PPT presentations should have a clear structure and be concise. Students/Participants should use visual elements, such as diagrams and graphs, to make information clear. After the presentation, students/attendees answer questions and participate in a discussion, thus developing communication skills. Through discussions and evaluation, students/participants develop the ability to argue and reach conclusions, which contributes to their professional competence.
- **Evaluation**- Evaluation of the teaching process and the achievements of students/participants play a key role in ensuring the quality of training and developing the competencies required for working in wind farms. Through systematic monitoring and assessment of knowledge and skills, with clearly defined checklists, teachers can recognize student/participant progress, spot areas that require additional explanation, and adjust teaching methods in accordance with individual needs.

The evaluation process can be conducted using a variety of methods, including:

- Tests - the classic way of checking theoretical knowledge through oral or written tests.
- Quizzes - a fast and interactive method that allows you to check key concepts and practical aspects through multiple choice questions. The manual offers quizzes made in Microsoft forms, but the teacher can also create new ones, adapted to the structure of students/participants.
- Practical exercises - assignments and simulations that allow students/participants to demonstrate understanding of procedures and application of acquired knowledge through practical work.
- Seminars and Research Papers - enable students to delve deeper into specific topics related to wind farm installation, maintenance and safety and develop analytical and presentation skills.
- Analysis of case studies - students/participants analyze real or hypothetical situations from practice, draw conclusions and propose solutions.

This approach to evaluation allows teachers to get a complete picture of the progress of students/students, while students/students develop both theoretical and practical knowledge needed to work in the sector of renewable energy sources. In addition to the proposed video material, quizzes and topics for seminar papers, the teacher can, at his discretion, propose video material himself, create appropriate quizzes, edit existing quizzes, create tests and assign topics for seminar papers.

All elements of teaching should be aimed at encouraging problematic content of a practical nature, so that students/participants independently come to conclusions when solving problems. Maximally applying and connecting theoretical knowledge to solve practical tasks and problems, students/participants will strengthen their ability to think independently. The goal is to acquire theoretical knowledge and skills that enable students/participants to better understand practical aspects and real challenges in the field of renewable energy sources, and prepare for the successful application of that knowledge in professional work.

Entry requirements - recommendation

Obtained education level III qualification in the field of electrical engineering, mechanical engineering or mechatronics. If the student/participant has obtained a qualification from another field or general education, it is necessary to master the general modules in the field of electrical engineering.

It is recommended that theoretical teaching in formal education be carried out with the whole class, and that groups for practical teaching number no more than 10 students. For non-formal education, it is recommended that the theoretical classes are realized with a maximum of 12 participants, and that the groups for the implementation of practical classes number a maximum of 3 participants.

1.2. Significance and application of wind energy

Guidelines for teachers:

In this part, teachers should provide students/students with:

- A basic understanding of the importance of using wind energy.
- Analysis of the labor market and employment opportunities in the sector of renewable energy sources.

Objective of the teaching unit:

- Acquaint students/participants with the importance of wind energy as a renewable source, its ecological and economic advantages, and the possibilities of application in the power sector.

Methodological recommendations for teachers

- Teaching with visual support - Use graphs and pictures of wind farms to help students/attendees better understand trends in wind energy applications.
- Question-driven discussion - By asking questions like "What are the key benefits of wind energy?" Encourage students/attendees to think and argue.
- Graphical data analysis - Students/Participants can analyze the graph of wind farm capacity growth and interpret trends. The teacher can ask students/students to predict how the wind energy industry will develop in the coming decades.

Evaluation:

- Critical Analysis - Students/Participants can discuss challenges related to wind energy (eg environmental impact, economic viability).
- End-of-class Q&A - Summarize key information through discussion and check student/attendee understanding by asking questions about the practical application of wind energy.

This approach allows students/participants to develop analytical and research skills, better understand the importance of wind energy and its practical applications, and look at global energy trends.

1.3. Structure of the manual

The manual is organized in such a way that it fully follows the content of the manual for students/trainees. It consists of eight chapters that deal in detail with the key aspects of working with power equipment in wind farms. Each chapter contains methodological guidelines for teachers, recommended teaching methods and evaluation criteria.

In the Introductionthe purpose and goals of the manual are presented and the structure of the manual is given, which shows the layout and subject matter of the chapters covered. There are also guidelines for teachers, recommendations for teaching, as well as entry requirements for the implementation of the teaching process.

Chapter 2, Renewable Energy Sources - An overview of the different forms of renewable energy sources, with a focus on wind energy.

Chapter 3, Safety at work and environmental protection - Safety measures and environmental protection when working on electric power equipment in wind power plants.

Chapter 4,Wind energy - Basic characteristics of wind energy and its application in wind power plants. Basic terms and types of wind turbines, their characteristics and classification criteria.

Chapter 5, Installation and dismantling of power equipment in wind farms - A key chapter that elaborates in detail the procedures for mounting and dismantling equipment in wind farms and procedures for practical implementation.

Chapter 6, Performing electrical installations in wind farms - Procedures for performing electrical installations in wind farms, including a brief description of grounding and lightning protection installations.

Chapter 7,Equipment maintenance and monitoring in wind farms - Preventive and corrective methods of maintenance of power systems, procedures for their implementation and monitoring in wind farms.

Material conditions and equipment - An outline list of equipment and teaching aids needed for the realization of theoretical and practical teaching.

At the end of the manual there are conclusions and recommendations, as well as literature and additional resources for further education of teachers and students/students.

2. RENEWABLE ENERGY SOURCES

Objective of the teaching unit

Students/Participants will get to know the basic principles of energy, its forms and role in modern society. Develop awareness of the importance of renewable energy sources, their role in reducing greenhouse gas emissions and sustainable development. Acquaint students/participants with types of renewable energy sources and their applications in modern energy systems.

Key topics

- The concept and basic characteristics of energy,
- Energy distribution according to different criteria,
- Non-renewable energy sources: characteristics, problems and challenges,
- Renewable energy sources: types, advantages and application possibilities,
- Solar energy and solar power plants (thermal power plants and photovoltaic power plants),
- Hydropower and hydropower plants (flow, storage, reversible),
- Wind energy and wind power plants (land, sea, hybrid),
- Sea and ocean energy (tides, waves, sea currents, ocean thermal energy),
- Geothermal energy and its applications (direct use and geothermal power plants),
- Biomass and biomass power plants (working principle, cogeneration systems),
- Advantages and challenges of applying renewable energy sources,
- Global and regional examples of renewable energy plants.

Teaching methods

- **Lecture and presentation**- Teachers explain basic concepts and principles, using illustrations, graphs and video materials.
- **Working in groups**- Students/Participants analyze different energy sources, their advantages and challenges.
- **Case studies**- Consideration of specific examples of renewable energy sources in the world and the region.
- **Practical exercises**- Research and analysis of local energy facilities (small hydropower plants, solar power plants, biomass power plants and geothermal systems).
- **Discussion and debate**- Arguing the advantages and challenges of different energy sources in the context of sustainable development.

Evaluation

- Quiz on key terms about renewable electricity sources.
- Independent task - Researching local or global renewable energy sources and making a short presentation about their role in the energy system.
- Essay or short term paper - Topic: How do renewable energy sources shape the future of energy?
- Critical analysis - Discussion on the challenges and possibilities of applying renewable energy sources in modern societies.
- Practical task - Analysis of energy plants in the region through a field trip or digital survey.

Exercise: Research work - Analysis of energy plants in the region

Exercise goal:

- Acquaint the students/participants with the types of renewable energy plants in the region.
- Develop research skills through the analysis of technical, economic and environmental aspects of power plants.

Instructions for execution:

Introduction

- Explain the basic types of power plants (small hydropower plants, solar power plants, biomass power plants, geothermal power plants).
- Discuss their importance for the local community and sustainable development.

Research

- Students/Participants collect data on selected power plants (location, capacity, technology, operators).
- They use reliable sources (government reports, energy companies, environmental organizations).

Analysis

- Assess the contribution of power plants in energy supply.
- Consider economic benefits and environmental impact.

Presentation of results

- Students/Participants make a short presentation or report.
- Discuss the future of renewable energy in the region.

Evaluation of research work:

- Creativity of presentation – Is the data clearly presented in a written paper or visual representation?
- Discussion and conclusions - Do the students/participants present the advantages and challenges of energy plants from renewable sources in their region?

Quiz 1: Renewable energy sources

https://forms.office.com/e/YZ1j2ZSCB0

1. What is the general definition of energy?

a) **Energy is the ability to do work.**
b) Energy can be created and destroyed.
c) Energy cannot be converted from one form to another.
d) Energy exists only in the form of electricity.

2. Which of the listed sources of energy is not renewable?

a) Solar energy
b) Wind energy
c) **Natural gas**
d) Hydropower

3. How do we share energy according to natural renewables?

a) Accumulated and transitional
b) Primary, transformed and useful
c) Conventional and unconventional
d) **Renewable and non-renewable**

4. What energy comes from chemical bonds between atoms?

a) Kinetic energy
b) **Chemical energy**
c) Nuclear energy
d) Electromagnetic energy

5. Which of the listed forms of energy is not a primary renewable energy source?

a) Geothermal energy
b) Biomass energy
c) **Nuclear fission energy**
d) Tidal energy

6. What energy is generated in the interior of the Earth?

a) Hydropower
b) **Geothermal energy**
c) Nuclear energy
d) Tidal energy

7. Which process enables the production of electricity in solar photovoltaic systems?

a) Nuclear fission
b) **Photoelectric effect**
c) Biomass combustion
d) Hydraulic cycle

8. What do flash steam geothermal power plants use as a working fluid?

a) Fuel oil
b) Wind
c) Natural gas
d) **Groundwater under high pressure**

9. What type of hydroelectric power plant uses the power of the tides?

a) Run-of-the-river hydroelectric power plants
b) Reversible hydroelectric power plants
c) Tidal power plants
d) Geothermal power plants

10. What enables hybrid solar power plants to work even in periods without solar energy?

a) Energy storage in batteries
b) Additional use of wind farms
c) Combination with diesel generators or hydropower
d) All of the above

11. Which of the factors most affects the efficiency of photovoltaic panels?

a) Wind speed
b) The position of the panel in relation to the Sun
c) The depth of the soil on which they are placed
d) Precipitation amount

12. What type of renewable energy source uses the temperature difference between the surface and deep layers of the ocean?

a) Hydropower
b) Biomass
c) OTEC - Ocean Thermal Energy Conversion
d) Nuclear energy

13. What type of solar power plant uses a heliostat field?

a) Photovoltaic solar power plant
b) Solar towers
c) Wind farm
d) Hydroelectric power plant

14. What is the basic characteristic of small hydropower plants?

a) They can only use groundwater
b) Their installed power is up to 10 MW
c) They have lower efficiency than large hydropower plants
d) They do not require any infrastructure

15. What type of energy is used in biomass power plants?

a) Nuclear energy
b) Organic matter of plant and animal origin
c) Kinetic energy of water
d) Electricity from the grid

16. Which system uses tidal currents to produce energy?

a) OWC systems
b) Geothermal power plants
c) Tidal power plants
d) Hydroelectric power plants on rivers

17. What technology uses mirrors in renewable energy sources?

a) Thermal solar power plants
b) Geothermal power plants
c) Wind turbines
d) Biomass power plants

18. Which type of hydroelectric power plant enables the storage and later release of water for the production of electricity?

a) Run-of-the-river hydroelectric power plants
b) Storage hydroelectric power plants
c) Reversible hydroelectric power plants
d) Biomass hydropower plants

19. What are the main sources of energy in the oceans and seas?

a) Tidal energy
b) Energy of ocean currents
c) Wave energy
d) All of the above

20. Which advantage best describes the use of renewable energy sources?

a) They do not pollute the environment and reduce CO2 emissions
b) They have unlimited supplies of fossil fuels
c) They are not subject to changes in climatic conditions
d) They do not require investments in infrastructure

Videos:

Types of renewable sources of electricity

https://www.energyencyclopedia.com/en/free-downloads/videos/types-of-res-and-the-use-of-renewable-56

Comparing renewable sources of electricity

https://www.energyencyclopedia.com/en/free-downloads/videos/comparison-of-renewable-energy-source-55

3. SAFETY AT WORK AND PROTECTION OF THE ENVIRONMENT

3.1. Possible hazards to the health and safety of workers when working on wind farms

Objective of the teaching unit:

Acquaint students/participants with the risks of working in wind farms and ways to reduce the risk by applying adequate protective measures.

Key topics:

- Extreme weather conditions (high and low temperatures, wind, humidity),
- Noise and vibrations that can cause health problems,
- Risks of working at height and application of protective equipment,
- Dangers of electric current (direct contact, step voltage, electric arc),
- Presence of dangerous substances and chemicals,
- Possibility of fire and explosion.

Teaching methods:

- Lecture with case studies,
- Analysis of accidents and discussion of preventive measures,
- Discussion on the procedure for providing assistance in the event of an accident,
- Group work on the recognition of risks to the health and safety of workers.

Evaluation:

- Analysis of behavior in simulated dangerous situations.

3.2. Application of safety and protection measures at work during the performance of works on wind power plants

Objective of the teaching unit:

Train students/participants to recognize and apply safety procedures when performing work on wind farms.

Key topics:

- Division of work according to the presence of voltage (work in a de-energized state, near voltage, under voltage),
- Personal and collective protective equipment,
- The five golden rules of safety,
- Organization of the work space and installation of protective partitions.

Teaching methods:

- Lecture with practical demonstrations of protective equipment,
- Group work on the identification of potential risks and the application of protection measures,
- A discussion on the importance of the "five golden rules",
- Workshops on the application of personal protective equipment.

Evaluation:

- Questions and answers at the end of the lesson - Summarize key information through discussion and check student/participant understanding by asking questions about the practical application of occupational safety and health measures when performing work on wind farms.

3.3. Implementation of safety measures and personal protection measures when working at height in wind power plants

Objective of the teaching unit:

Train students/participants in the application of safety measures and the use of personal protective equipment when performing work at height in wind farms.

Key topics:

- Locations of work at height (wind turbine towers, access platforms, gondolas, specialized access systems).
- Dangers when working at height (loss of balance, unfavorable weather conditions, inadequately prepared surfaces).
- Personal protective equipment and equipment for working at height (safety helmets, safety belts, anchor points, fall protection systems).
- Work environment factor review procedure and risk identification.
- Evacuation and emergency response procedures in the event of an accident.

Teaching methods:

- Lecture with visual support (pictures and video materials on the rules of protection at height).
- Demonstration of proper use of seat belts and other equipment.
- Group risk analysis in simulated working conditions
- Discussion of real examples of accidents and their causes.
- Simulation of the working situation using models and safety equipment.

Evaluation:

- Quiz on the application of safety and protection measures at work during the execution of works at the wind power plant
- Analysis of real accidents and discussion of preventive measures.
- Practical verification of knowledge through the implementation of a given practical exercise.

Practical exercises:

Task 1: Evacuation simulation

Exercise goal:

Students/Participants will learn the proper use of safety equipment, coordination of evacuation in emergency situations and application of safety procedures when working at height.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Provide a safe environment for conducting the evacuation simulation.
- Install anchor points and check the correctness of all seat belts and carabiners.
- Divide roles in the team.

Explanation of the task:

- Point out the importance of proper application of safety equipment and team coordination.
- Demonstrate the correct placement of the seat belt and attachment to the anchor point.

- Explain how to communicate with the team in emergency situations and how to conduct an evacuation.

Running the simulation:

- Give the signal to start the evacuation simulation.
- Observe how the team implements the evacuation plan and how the workers communicate during the procedure.
- Ensure that exercise is carried out in controlled and safe conditions.

Evaluation and final check:

- Analyze the way the exercise is performed and identify possible mistakes.
- Talk to participants about challenges and ways to improve.
- Provide feedback on the effectiveness of teamwork and correct use of safety equipment.

Task 2: Simulation of rescue from height

Exercise goal:

Students/Participants will practice emergency rescue procedures from a height, including proper use of safety nets, casualty lowering systems and team coordination during intervention.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Provide a suitable place for the rescue simulation, with safety measures to prevent injuries.
- Inspect the safety net, ropes, pulleys and carabiner clips to check the correctness of the equipment.
- Set clear roles in the team (supervision person, network stability person, rescue person).

Explanation of the task:

- Demonstrate safety net deployment procedures and use of rescue equipment.
- Explain how to react quickly and effectively in the event of a worker falling from a height.
- Explain the method of communication during rescue and the importance of timely reaction.

Running the simulation:

- Give the signal to start the rescue simulation.
- Observe how the team organizes the rescue, sets up the safety net and uses the system to lower the injured worker.
- Ensure that all procedures are performed according to safety protocols.

Evaluation and final check:

- Analyze how effectively the rescue was carried out.
- Identify possible omissions and suggest improvements.
- Discuss with participants the challenges during the simulation and the importance of precise coordination.

Quiz 2: Application of safety and protection measures at work during the performance of works on wind farms

https://forms.office.com/e/gbHp9CACVp?origin=lprLink

1. What are the main risks when working at height in wind farms?

a) Fall from a height
b) Noise and vibrations
c) Chemical poisoning
d) Improper waste storage

2. What effects of electric current can lead to burns?

a) Biological
b) Mechanical
c) Thermal
d) Electrochemical

3. What is the name of the rule that includes disconnection of the voltage and insurance against reconnection?

a) Five golden rules
b) Security code
c) Isolation rule
d) Protection standard

4. Induced voltage can be dangerous when working on electrical installations.

a) Exactly
b) Incorrect

5. Which protective means belong to personal protective equipment?

a) Safety helmets, gloves and safety belts
b) Isolation partitions and warning signs
c) Safety signs and collective protective fences
d) Emergency evacuation routes

6. What are the first steps in helping a person with an electric shock?

a) Checking breathing and pulse
b) Power off
c) Direct withdrawal of the casualty
d) Use of water to cool the body

Note for teachers:

- It is recommended that the simulation be carried out in cooperation with occupational safety experts or with companies dealing with industrial protection.
- At the end of the exercises, allow the students/participants to ask questions and further discuss the real challenges of evacuation and rescue in an industrial environment.

Videos:

Simulation of a fall from a wind farm gondola

https://www.youtube.com/watch?v=UWSckm8zTc8

Use and characteristics of parts of personal protective equipment

https://www.youtube.com/watch?v=nA9oC--tq50

3.4. Implementation of measures to reduce the negative impact of wind power plants on the environment

Objective of the teaching unit:

Develop students'/participants' awareness of the possible negative impacts of wind farms on the environment and familiarize them with measures that can reduce these impacts through proper planning, technical innovation and sustainable resource management.

Key topics:

- Negative impacts of wind farms on the ecosystem (habitat degradation, risk to birds and animals, noise, electromagnetic interference).
- Procedures to reduce negative effects (proper site planning, blade design optimization, bird monitoring system, noise reduction).
- Recycling and circular economy in the wind power sector.
- Examples of good practice from around the world.

Teaching methods:

- Lecture with discussion - the teacher can explain the key aspects of environmental challenges and protection measures.
- Case study analysis – students/attendees can investigate examples from practice (eg radar systems in Spain that prevent bird collisions with turbines).
- Group discussion - students/attendees can discuss the advantages and challenges of recycling wind turbines.
- Practical exercises - Waste management and application of protective equipment when implementing environmental protection measures

Evaluation:

- Independent task - research on ways of recycling wind turbines in different countries and analysis of their sustainability.
- Essay or short term paper - students/participants can write on the topic: How do technologies reduce the negative environmental effects of wind farms?
- Critical analysis - a discussion of the balance between the benefits of wind farms and their impact on the environment.
- Practical verification of knowledge through the implementation of a given practical exercise.

Practical exercises:

Task 1: Waste management in the wind farm

Exercise goal:

Students/Participants will learn to properly identify, sort and store waste generated during the operation and maintenance of the wind farm, while respecting environmental standards and prescribed procedures for recycling and reusing materials.

Instructions for performing the exercise:

- Before the start of the exercise, hold a short theoretical lecture on the types of waste in the wind power industry and the environmental regulations for its disposal.
- Divide the students/participants into smaller groups and assign them specific tasks related to the identification, classification and proper storage of waste.
- Show examples of proper labeling and packaging of waste according to industry standards.
- Provide students/participants with practical work with real or simulated waste materials (paper, plastic, metal, electronic waste) in order to learn methods of classification and storage.
- In the final phase of the exercise, analyze the sorting procedures and discuss the possibilities for improving the process of recycling and reuse of materials.

Final check:

- The teacher will check whether the students/students have sorted the waste correctly and whether the containers are correctly marked.
- During the discussion, students/participants will explain their sorting decisions and make suggestions for improvements.
- Students/Participants can prepare short reports on environmental regulations and their application in the wind farm industry.

Task 2: Application of protective equipment during the implementation of environmental protection measures

Exercise goal:

Students/Participants will learn the proper use of personal protective equipment when handling waste materials and chemicals in a wind farm, as well as the implementation of proper packaging and transportation procedures for hazardous waste.

Instructions for performing the exercise:

- Before carrying out the exercise, the teacher should explain the importance of personal protective equipment when working with waste materials and chemicals.
- Show students/attendees the proper use of protective equipment (gloves, masks, protective suits and footwear) and emphasize regulations on handling hazardous materials.
- Divide the students/participants into teams and give them an exercise simulating the handling of hazardous waste, including proper packaging and labeling of materials.
- During the exercise, monitor the correctness of procedures and point out possible omissions in the handling of protective equipment and waste.
- At the end of the exercise, organize a discussion about challenges and potential improvements in environmental protection, when working in wind farms.

Final check:

- Check whether students/attendees have correctly used protective equipment and whether they have correctly handled waste and chemicals.
- Analyze student/participant reports on hazardous materials handling and discuss opportunities to improve procedures.
- Students/Participants can propose additional measures to improve safety and environmental efficiency in waste management.

Note for teachers:

When performing these practical exercises, it is important to provide a safe working environment and ensure that students/participants are familiar with all safety protocols before starting work.

If possible, it is recommended to carry out exercises in a real industrial environment, in cooperation with local companies.

Teachers should encourage students/students to think critically and propose solutions to improve the process of waste management and environmental protection, as these are key aspects of sustainable development in the renewable energy sector.

4. WIND ENERGY

Objective of the teaching unit:

Acquaint students/participants with the basic principles of the creation and application of wind energy, its characteristics and importance for renewable energy sources.

Key topics:

- Definition and origin of wind,
- The influence of atmospheric factors on wind speed and direction,
- Wind strength measurement (wind vane, Beaufort scale),
- Wind energy potential and formula for calculating wind power.

Teaching methods:

- Lecture with visual displays and simulations,
- Analysis of wind speed data from the local weather station,
- Discussion on the influence of geographical factors on wind power.

Evaluation:

- Working in groups: an analysis of the Beaufort scale.

4.1. Basic applications of wind energy

Objective of the teaching unit:

To present students/participants with ways of using wind energy, historical development and modern technologies of wind power plants.

Key topics:

- The historical development of the use of wind energy,
- Modern wind power plants and wind generators,
- Advantages and challenges of using wind energy,
- Global trends in wind power generation.

Teaching methods:

- A discussion on the historical development and examples of the use of wind energy,
- Group work: analysis of data on wind energy production in different countries.

Evaluation:

- Exercise - research paper: Investigate the installed capacity in your region and compare it with the world market in the field of wind power plants,
- Presentation of research work of students/participants.

Exercise:

Research the installed capacity in your region and compare it with the world market

Exercise goal:

Students/Participants will research the capacities of wind farms in their region and compare them with global data, analyzing the importance and trends in the renewable energy sector.

Instructions for performing the exercise:

Introductory explanation- Explain the concept of installed capacities of wind power plants (expressed in MW and GW) and the importance of wind energy in the energy system.

Research- Students/Participants individually or in groups collect data on local wind farms (capacity, location, number of turbines) from official sources and compare them with global data (IRENA, IEA).

Analysis and comparison- Students/Participants identify the advantages and challenges of wind power development in the region and how it fits into global trends.

Presentation of results- Each group prepares a short report or presentation, and the teacher leads a discussion on the possibilities of sector development.

Note:

This activity develops research and analytical skills and can be extended using graphs, interactive maps and energy simulations.

4.2. Characteristics of wind farms

4.2.1. Definitions of wind turbines and wind farms

Objective of the teaching unit:

Acquaint students/participants with the basic concepts of wind turbines and wind power plants, their functions and importance in the production of electricity.

Key topics:

- Definition and purpose of wind turbines,
- Principle scheme of wind energy conversion into electrical energy.

Teaching methods:

- Lecture with visual displays and animations,
- Group discussion on the conversion of wind energy into electricity.

Evaluation:

- Work in groups - analysis of the key characteristics of wind farms.

4.2.2. Types of wind turbines and their characteristics

Objective of the teaching unit:

Present to students/participants different types of wind turbines and their characteristics.

4.2.2.1. Wind turbines according to the position of the shaft

Objective of the teaching unit:

To acquaint students/participants with the division of wind turbines according to the position of the shaft, the differences between turbines with a horizontal and vertical axis, their advantages, disadvantages and application in practice.

Key topics:

- Basic characteristics of wind turbines with a horizontal axis of rotation (VSHO),
- Advantages and disadvantages of VSHO turbines,
- Basic characteristics of wind turbines with a vertical axis of rotation (VSVO),
- Types of VSVO turbines: Darius turbine, Gyromil turbine, Gorlov turbine, H-type, Cilko turbines, Savonius turbine,
- Advantages and disadvantages of VSVO turbines.

Teaching methods:

- Lecture with multimedia displays - The teacher uses images and video materials to visually explain the differences between horizontal and vertical axis turbines.
- Discussion and analysis of advantages and disadvantages - Students/Participants discuss which turbines are more efficient and in which situations they are applicable.
- Work in groups - Students/Participants compare the characteristics of two types of turbines and conclude which one is more suitable for certain climatic and geographical conditions.

Evaluation:

- Critical Analysis - Students/Participants discuss challenges related to the application of VSHO and VSVO turbines and possible innovations in their design.

4.2.2.2. Wind turbines according to the type of wind generator

Guidelines for teachers: According to the type of wind generator

Objective of the teaching unit:

To acquaint students/participants with different types of wind generators, their working principles, advantages and disadvantages, and criteria for choosing the appropriate technology in wind power plants.

Key topics:

- Basic types of wind generators,
- Wind turbines with induction cage wind generator,
- Wind turbines with a synchronous machine and a variable speed turbine,
- Wind turbines with a double-sided induction machine,
- Wind turbines with multi-pole synchronous machine with direct drive,
- Comparison of different types of generators according to efficiency, stability, way of connecting to the grid and economic profitability,
- Application of frequency converters and wind turbine speed control.

- Advantages and limitations of different types of generators depending on the location and power of the wind farm.

Teaching methods:

- Lecture with multimedia displays - The teacher uses pictures, diagrams and video materials to show the operation of different types of wind generators.
- Discussion and analysis of advantages and disadvantages - Students/Participants discuss which type of wind generator is the most efficient and under which conditions it is used.
- Working in groups - Each group is given the task of analyzing one type of wind generator and presenting its key features, advantages and disadvantages.

Evaluation:

Independent task - Students/Participants analyze which type of wind generator would be most suitable for certain climatic and infrastructure conditions.

4.2.2.3. Wind turbines according to the autonomy of the operating mode

Objective of the teaching unit:

To acquaint students/participants with the division of wind power plants according to the mode of operation and connection to the power grid, including on-grid, off-grid and hybrid systems. Analyze the advantages and limitations of each type, as well as their application in different energy environments.

Key topics:

- *On-grid*wind farms - Directly connected to the grid, stabilization of the power system, adaptation to consumption.
- Off-grid wind farms - Stand-alone systems for remote areas, energy storage via batteries, advantages and challenges.
- Hybrid wind farms - Combination of wind with other sources (solar panels, diesel generators, energy storage systems).
- Application of energy storage - Optimization of consumption and stabilization of energy supply.

Teaching methods

- Teaching with visuals - Using illustrations to show the operation of different types of wind farms.
- Discussion - Consideration of the advantages and challenges of each system and the possibility of their application in local conditions.

Evaluation:

- Independent task - Students/Participants analyze which type of wind farm would be most suitable for a specific region based on climate and infrastructure factors.

4.2.2.4. Wind turbines according to location

Objective of the teaching unit:

Familiarize students/attendees with the types of wind farms by location, including onshore, offshore and high-altitude wind farms. Analyze their advantages, limitations and impact on the environment and the power system.

Key topics:

- Onshore wind farms - Characteristics, advantages and challenges of onshore wind farms.

- Offshore wind farms - Difference between offshore and floating wind farms, advantages and technical challenges.
- High-altitude wind farms - Emerging technologies and the potential of harnessing wind at high altitudes.
- Factors when choosing a location - Wind speed and stability, distance from the power grid, environmental aspects.

Teaching methods:

- Teaching with visuals - Using photos and video material about different types of wind farms.
- Case Study Analysis - Exploring examples of the largest onshore and offshore wind farms in the world and discussing their strengths and challenges.

Evaluation:

- Independent task - Students/Participants research the most suitable locations for installing wind farms in their country.
- Critical Analysis - Students/Participants discuss the impact of offshore wind farms on the marine ecosystem and bird migration.

Videos:

Principle of operation of offshore wind power plants

https://www.youtube.com/watch?v=HqCVgRbPQcg

4.2.2.5. Wind turbines according to power

Objective of the teaching unit:

Acquaint students/participants with the classification of wind power plants according to power, the differences between small and large wind power plants, and their role in the power system.

Key topics:

- Small wind farms - Characteristics, application, advantages and limitations.
- Large wind farms (wind farms) - Capacities, infrastructure and economic profitability.
- Distributed energy production - The role of small wind turbines in local communities.

Teaching methods:

- Lecture with examples - Explaining the differences between small and large wind farms with visuals.
- Case Study - Study of local or global wind farms, such as London Array or Horns Rev.
- Group work - Students/Participants research examples of small wind farms that can work in their region.

Evaluation:

- Research work - Students/Participants analyze the capacities of wind farms in their region and compare them with world trends.
- Discussion - Debate on the advantages and limitations of large wind farms versus small systems.

Exercise:

Study examples of wind farms in your region

Objective of the research work:

Students/Participants will analyze what types of wind farms exist in their region, classify them according to different criteria (shaft position, type of generator, operating autonomy, location, power) and compare them with global examples.

Research steps:

Collecting data on wind farms in the region

- Identify existing wind farms in the region.
- Find information about their capacity, type of wind turbine and location.
- Use sources such as official energy agencies, municipal reports and online databases.

Classification of wind power plants according to key parameters

- Shaft position: Are these wind turbines with a horizontal or vertical shaft?
- Type of generator: What technology is used to generate power?
- Operating mode autonomy: Are the systems on-grid, off-grid or hybrid?
- Location: Are they on land, sea or are new concepts being developed such as high altitude wind farms?
- Power: Are they small wind farms or large wind farms?

Comparison with global examples

- Explore examples of wind farms in other countries that use similar or different technologies.
- Compare the power and efficiency of local power plants with large global projects (eg London Array, Horns Rev).
- Identify which types of wind farms are dominant in the region, compared to global trends.

Analysis of advantages and challenges of local wind farms

- What are the advantages of existing wind farms in the region (availability of resources, economic profitability, environmental aspects)?
- What are the main challenges in their construction and exploitation (location conditions, energy policy, maintenance)?
- Are there opportunities for capacity improvements or expansions?
- Presentation of research results
- Students/Participants can prepare a written report, PowerPoint presentation or poster with summary data and illustrations.
- It is preferable to include graphs and maps to make the analysis more visually clear.
- Finally, students/attendees can discuss the future of wind energy in their region.

Evaluation of research work:

- Creativity of presentation – Is the data clearly presented in a written paper or visual representation?
- Discussion and conclusions - Do the students/participants present the advantages and challenges of wind farms in their region in an argumentative manner?

4.2.3. The structure of the wind farm

Objective of the teaching unit:

To acquaint students/participants with the structure of the wind farm, its basic systems and functions that enable efficient production of electricity.

Key topics:

- Wind turbine system and its main elements,
- Network connection system and power connection,
- Management and control center,
- Energy storage system,
- Condenser-filter plant.

Teaching methods:

- Teaching the theoretical part of the teaching unit,
- Group analysis of the functionality of individual systems,
- Discussion on the role of wind farms in the power grid.

Evaluation:

- Working in groups: analysis of parts and their functions.

4.2.4. Wind turbine elements

Objective of the teaching unit:

Explain to students/participants the basic elements of wind turbines, their functions and importance in the process of electricity production.

Key topics:

- Characteristics of wind turbine elements.

Teaching methods:

- Studying blueprints and models of wind turbines,
- Review of video material,

Evaluation: Wind turbine elements quiz.

Quiz 3: Wind turbine elements

https://forms.office.com/e/he6v3JvUPD

1. What are the basic elements of a wind turbine rotor?

- **a) Blades, rotor head, shaft**
- b) Transformer, tower, cables
- c) Anemometer, wind vane, capacitor battery
- d) Hydraulic brake, multiplier, generator

2. Which component of the wind turbine is used to measure wind speed?

- a) Weather vane
- **b) Anemometer**
- c) Capacitor battery
- d) Multiplier

3. What type of generator is most often used in wind farms?

- a) Synchronous generator
- b) DC generator
- **c) Asynchronous induction generator**
- d) Multiplier generator

4. Which system allows the nacelle to turn in the direction of the wind?

- **a) Gondola rotation system**
- b) Brake system
- c) Power transmission
- d) Fire protection system

5. The role of the capacitor bank is to stabilize the voltage in the wind turbine system.

- **a) Exactly**
- b) Incorrect

6. Which element allows changing the voltage produced in the wind turbine into the appropriate voltage for the network?

- a) Grounding
- **b) Transformer**
- c) Hydraulic brake
- d) Weather vane

7. Which component is used to regulate the angle of the blades in order to optimize the operation of wind turbines?

- a) Gondola rotation system
- **b) Blade rotation system**
- c) Brake system
- d) Anemometer

8. Which device enables monitoring and remote control of the operation of wind turbines?

- a) Generator
- b) Capacitor battery
- **c) Monitoring and management system**

d) Multiplier

9. Which component serves to protect wind turbines from overload and electrical failures?

a) Grounding
b) Transformer
c) Fire protection system
d) Safety devices

10. Which component is used to reduce the rotational speed of a wind turbine in case of an emergency stop?

a) Hydraulic brake
b) Multiplier
c) Anemometer
d) Weather vane

Videos:

Wind turbine operation simulation

https://www.youtube.com/watch?v=TXHAkE6I0rE

4.2.5. Material, tools, equipment and devices for work on the construction and maintenance of wind farms

Objective of the teaching unit:

Acquaint the students/participants with the types of materials used in the construction and maintenance of wind power plants, their properties and methods of application.

Key topics:

- Material
- Tool
- Equipment and devices
- Specialized machines and vehicles

Teaching methods:

- Lecture with demonstration of material samples,
- Analysis of technical specifications of cables and connections,
- Discussion on material selection criteria.

Evaluation:

- Recognition of various types of conductors and cables and elements for connection and protection,
- A practical test of the ability to properly use certain tools.

Practical exercises:

Task 1: Using hand and power tools

Exercise goal:

Students/Participants will acquire practical skills in the use of basic hand and power tools used in electrical installations, with an emphasis on safety and work efficiency.

Instructions for performing the exercise:

- Introduction to explain the basic functions and rules of using hand and electric tools in electrical installations.
- Demonstrate the correct use of tools, with an emphasis on technical features and safety measures.
- Divide students/participants into groups and assign them practical tasks involving the use of various tools.
- During the exercise, supervise the students/participants and check their accuracy, work safety and efficiency in the use of tools.
- Discuss the most common mistakes when using the tool and how to avoid them.
- At the end of the exercise, analyze the accuracy and safety of the work of each student/participant and give recommendations for improving the work technique.

Final check:

- Check the correct handling of tools through the demonstration of practical tasks.
- Assess how well students/participants understood safety procedures and rules when working with hand and power tools.
- Based on the discussion, determine whether students/participants can recognize the appropriate tool for specific installation tasks.

Task 2: Identification and analysis of materials

Exercise goal:

Students/Participants will learn how to identify and analyze different types of materials used in electrical installations, understand their properties and select the appropriate material for specific working conditions.

Instructions for performing the exercise:

- Before starting the exercise, the teacher should hold a short introductory lecture about the types of materials used in electrical installations and their characteristics.
- Explain the importance of the correct choice of materials depending on the working conditions, durability and safety of electrical installations.
- Divide the students/participants into teams and assign them tasks related to the recognition and analysis of the material.
- Provide technical documentation, manufacturers' catalogs and material samples so that students/attendees can practically analyze the properties of different conductors and insulation materials.
- Students/Participants should compare the materials and identify their advantages and disadvantages through discussion and measurement of certain parameters.
- During the exercise, supervise the students/participants, correct any mistakes and indicate the factors that influence the choice of materials for electrical installations.

- At the end of the exercise, organize a presentation of the results of each group and discuss the selection of materials in specific working conditions.

Final check:

- Check the accuracy of material recognition and the correctness of the conclusions reached.
- To analyze how well the students/participants understood the technical specifications and how they can apply them in practice.
- Based on the discussion, assess how well students/participants can independently select the appropriate material for different installations.

Videos:

A specialized aircraft for the transport of wind farm equipment

https://www.youtube.com/watch?v=EDnLqOqfKaU

5. ASSEMBLY AND DISASSEMBLY OF ELECTRICAL GENERATORS - GETSKE EQUIPMENT IN WIND POWER PLANTS

5.1. Preparation of the terrain for the installation of power equipment in wind farms

Objective of the teaching unit:

Acquaint students/participants with the basic principles of ground preparation for the installation of power equipment in wind farms, including types of foundations, trenches and power connections.

Key topics:

- Types of foundations for wind turbines (concrete, steel, floating),
- Preparation of trenches for laying cables - depth, protection and marking,
- Installation of power connections and grounding system,
- Standards and regulations for field preparation,
- Testing and inspection of electrical installations before installation of equipment.

Teaching methods:

- Lecture with visual representations - Explanation of the types of foundations, trenches and power connections through technical illustrations and pictures from practice.
- Discussion and group work - Identification of challenges in field preparation depending on location and environmental factors.

Evaluation:

- Analysis of technical solutions - Students can analyze different types of foundations and trenches and draw conclusions about their application in different conditions.
- Discussion and practical assessment – Evaluation of the student/participant's understanding through the exchange of opinions on challenges and standards in the field preparation process.

5.2. Assembling and disassembling the assembly structure of equipment in wind power plants

Objective of the teaching unit:

The aim of this teaching unit is to acquaint students/participants with the types of assembly structures in wind farms, the assembly and disassembly processes of key elements (tower, nacelle, supports, pedestals, container structures) and the procedures for transporting and disposing of equipment. Special focus is on technical standards, safety measures and practical challenges in work.

Key topics

- Tower and nacelle of wind turbines - characteristics important for assembly and disassembly,
- Types of towers (steel, concrete, hybrid),
- The function of the nacelle and its components,
- The process of assembling and disassembling the tower and gondola,
- The procedure for mounting and dismounting the base and supports of electrical installations,
- The function of supports and bases in wind power plants,
- Steps of assembly and disassembly of power infrastructure,
- The connection of the carrier with electrical installations,
- Constructions for meteorological equipment and security cameras,
- The role of meteorological sensors in optimizing the operation of wind farms,
- Placement and installation method of security cameras,
- The influence of weather conditions on installations,
- Containers for transformer stations and energy storage systems,
- The function of container structures in wind farms,
- The process of assembling containers and equipment inside them,
- Safe disconnection and dismantling of container power systems,
- Transport and disposal of equipment,
- Methods of recycling and reuse of components,
- Environmental standards for disposal of equipment,
- Dismantling procedures in accordance with safety regulations.

Teaching methods

- Lecture and visualization – The teacher uses pictures and videos of the assembly and disassembly process.
- Case discussion and analysis – Students/Participants analyze examples of wind farms and their prefabricated structures, relying on the seminar papers done in the previous chapter.
- Research tasks - Students/Participants study the performance of tower structures and ways of optimizing their assembly.

Evaluation

- Quiz on prefabricated constructions and their technical characteristics.
- Case study analysis: students/participants compare different types of wind farm towers and their advantages, based on previously collected data.

Research task - Study of examples of different constructions of wind turbine towers

Task: Students/Participants should research and compare different types of towers used in wind farms (steel tubular towers, concrete towers, hybrid towers).

Instructions:

- Find information about the materials, advantages and disadvantages of each type of tower.
- Describe the factors that influence the choice of a particular type of tower (eg location, height of the wind turbine, construction costs).
- Present the data in a table and make a short conclusion.

Form of work: Independent/group research with the creation of a written report or PowerPoint presentation.

Evaluation of research work:

- Creativity of presentation – Is the data clearly presented in a written paper or visual representation?
- Discussion and conclusions - Do the students argue the advantages and challenges of different wind turbine tower constructions?

Quiz 4 - Testing knowledge about prefab structures in wind farms

https://forms.office.com/e/H4qvBw4qju

1. What is the basic function of prefabricated structures in wind farms?

a) Increasing wind speed?
b) Ensuring stability and accommodation of equipment
c) Temperature regulation
d) Electricity generation

2. What are the key factors that influence the choice of the type of wind turbine tower?

a) The color and shape of the tower
b) Height, stability and construction material
c) Number of rotor blades
d) Energy storage capacity

3. What is installed first during the assembly of the wind turbine tower?

a) Generator
b) Rotor
c) Tower foundations
d) Gondola

4. What equipment is necessary for mounting the gondola on the tower?

a) Hand tools and electric drills
b) Specialized cranes and safety mechanisms
c) Cable carriers and transformers
d) Laser leveling devices

5. What is the main reason for dismantling wind turbines?

a) Generator oil change
b) End of life or system modernization
c) Reduction in the number of wind farms in the world
d) Lack of wind in certain locations

Videos:

Detailed view of the assembly of the tower and gondola.

https://www.youtube.com/watch?v=fI6BMVw_B-Y

Educational video about wind turbines.

https://www.youtube.com/watch?v=vjqdJ8OSmRA

Installation of wind turbines of an off-shore wind power plant

https://www.seetaoe.com/details/129354.html

Group discussion - Problems and challenges in dismantling wind turbines

Task: Organize a discussion in which students/participants analyze the key challenges in dismantling wind turbines and propose solutions.

Discussion questions:

- What are the biggest challenges during the installation of a wind farm tower?
- How to ensure the stability of the tower in strong gusts of wind?
- What are the main technical problems when dismantling towers and nacelles?
- How can safe dismantling be ensured in extreme weather conditions (eg offshore wind farms)?
- How is the transportation and recycling of materials handled after dismantling?
- What can be improved in the dismantling process in order to reduce the costs and time of the works?
- What could improve the safety of workers during the assembly and disassembly of wind turbines?

5.3. Assembly/disassembly and connection of power equipment in wind power plants

Objective of the teaching unit:

To enable students to understand and master the processes of assembly, disassembly and connection of power equipment in wind farms. Through theoretical teaching and practical exercises, students will gain knowledge about the key components of the nacelle, monitoring and control systems, connecting electrical components and cables, and testing power systems.

Key topics:

Assembly of the nacelle with factory-integrated mechanical and electrical equipment

- The role of the nacelle in the power system of the wind farm,
- The process of raising and setting up the nacelle,
- Safety measures during assembly.

Mounting and dismounting of monitoring and control systems

- Sensors and devices for monitoring temperature, vibrations and other parameters,
- Remote control and communication systems,
- Device connection and disassembly procedure.

Connecting the electrical components inside the nacelle of the wind turbine

- Connecting the generator to the converter system,
- Installation and connection of the control system,
- Connection of protection and security systems,
- Laying and connecting power cables inside the nacelles,
- Final testing and verification of the system.

A system for storing electricity in a wind farm

- The role of battery storage and supercapacitors,
- Installation of the storage system and integration with the network,
- Procedure for safe disassembly and discharge of batteries.

Teaching methods:

- Lecture and explanation - The teacher will present the students with the theoretical foundations and technical principles of assembly and disassembly of power systems in wind farms.
- Demonstration - Using video and pictures, the teacher will demonstrate the key procedures for connecting electrical components.
- Research assignment - Students will research methods of connecting power equipment in different types of wind turbines and prepare a short presentation.

Evaluation:

- Quiz on assembly and connection of power equipment.
- Independent task - Students can investigate and describe the procedure for connecting the power equipment in the nacelle of the wind turbine.

Exercise:

Research task: The process of connecting power equipment in the gondola

Objective of the task

This research assignment allows students to gain a deeper understanding of the power equipment connection procedures inside a wind turbine nacelle. Through the analysis of different configurations and connection methods, students will develop analytical and research skills, and critically look at the challenges in the operation of power systems in wind farms.

Instructions for implementation

Introductory lecture

- Explain to the students the basic components of the power system in the nacelle of the wind turbine (generator, converter, distribution cabinet, protection and grounding system).
- Point out the differences in the connection of power equipment at onshore and offshore wind farms.
- Discuss safety aspects when working with high voltage cables and protective systems in the nacelle.

Division of students/participants into groups or individual work

- Divide students/participants into smaller groups or allow individual research, depending on the number of students/participants and available resources.
- Each group can handle one of the key aspects of the research.

Conducting research

- Students/attendees use the Internet, professional articles, technical reports and video materials to gather information on methods of connecting electrical power components.
- I can contact experts or companies in the field of electricity and wind power for additional information.

Analysis and preparation of results

- Students analyze the collected data and create short reports or presentations in PowerPoint.
- Key research points should be covered, including the advantages and challenges of different linkage methods.

Presentation of research findings

- Each group or individual presents the results of their research through a short PowerPoint presentation or oral report to the class.
- Other students ask questions and discuss researched topics to encourage critical analysis and exchange of ideas.

Evaluation of research work:

Understanding the key aspects of connecting power equipment in the nacelle.

Creativity of presentation – Is the data clearly presented in a written paper or visual representation?

Discussion and conclusions - Active participation in the discussion and the ability to critically analyze the researched topic

Recommendations for educational implementation

There are no practical exercises in this chapter, but teachers can use the following methods to better familiarize students with the procedures for mounting and connecting electrical equipment:

- Video materials:
- "Wind Turbine Electrical Installation" - connection of generators and power systems.
- "Wind Turbine Commissioning Process" - final testing and verification.
- "High Voltage Cable Installation in Wind Farms" - laying and connecting cables.
- Discussion questions:
    1. What are the main advantages of factory integrated nacelle systems?
    2. How to ensure the stability of electrical connections during strong vibrations?
    3. What are the key challenges in connecting generators to the grid?

Quiz 5 - Assembly and connection of power equipment

https://forms.office.com/e/85wh4EzhsW

1. What is the basic function of the wind turbine nacelle?

a) Wind speed reduction
b) Provision of protection against atmospheric influences
c) Accommodation of key power components
d) Power transmission to the grid

2. What is the basic function of a converter in a wind turbine?

a) Transmission of mechanical energy to the rotor
b) Stabilization of variable frequency for the needs of connection to the network
c) Wind speed monitoring
d) Storage of electrical energy

3. What are the basic steps when connecting the generator to the converter system?

a) Connecting the power cables, calibrating the sensor and setting up the control software
b) Checking the electrical connections, connecting the generator to the converter, grounding and checking the phase sequence
c) Mounting the nacelle, testing the turbine blades and connecting the ground
d) Laying cables, connecting the distribution cabinet and testing the PLC system

4. What protective component is used to protect against lightning strikes?

a) Thermal sensor
b) Surge protection relay
c) Gas circuit breaker and varistor
d) Mechanical switch

5. Which of the following systems enables automatic control of wind turbines?

a) Mechanical brake
b) PLC controller
c) Hydraulic system
d) Heat sensor

6. What are the main parts of the cable system inside the nacelle?

a) Power cables, distribution cabinet and protective supports
b) Metal rails and insulating plates
c) Thermal cameras and measuring sensors
d) Capacitors and fuses

7. What are the key steps of testing the electrical components inside the nacelle?

a) Visual inspection, measurement of electrical parameters, test operation and adjustment of the control system
b) Just checking the safety cables
c) Insulation resistance testing only
d) Shutting down wind turbines without additional tests

5.4. Selection of protective equipment and equipment for assembly and disassembly of wind farm elements

Objective of the teaching unit:

Students will gain knowledge about the types of personal, collective and electrical protective equipment that is used when assembling and disassembling elements of a wind farm. Also, they will learn how to properly use protective equipment and what are the key procedures to ensure safety at the wind farm construction site.

Key topics

- Personal protective equipment (PPE) – The role of helmets, safety belts, protective clothing and footwear, hearing and vision protection in work at height and electrical installations.
- Collective protective equipment - Safety nets, barriers, lightning protection systems and signaling on the construction site.
- Electrical Protective Equipment – Dielectric gloves and footwear, tools with insulated handles, voltage testers and electrical shock protection systems.
- Procedure for checking and using protective equipment - Standard operating procedures for checking and proper use of protective equipment.
- Emergency measures and evacuation plan – Gondola and tower evacuation, height rescue training and use of first aid equipment.

Teaching methods

Introductory lecture and discussion

- Explain the importance of protective equipment and safety procedures during assembly and disassembly of wind farm elements.
- Point out the differences between personal, collective and electrical protection.
- Discuss with students the risks of working at height and handling electrical equipment.

Practical demonstrations

- Demonstrate the correct use of protective equipment (safety belt, helmets, dielectric gloves).
- Explain the safety testing of protective equipment and the inspection procedure.

Working in groups

- Each group does a practical exercise in the use of protective equipment (safety belt, helmets, dielectric gloves).
- Task: Write a seminar paper/PPT on personal or collective protective equipment at wind power plant construction sites.

Evaluation

- Quiz on protective equipment and safety procedures.
- Practical Check – Demonstration of proper use of personal protective equipment and safety procedures.
- Evaluation of the seminar work - Analysis of collective protective equipment through the seminar work and presentation.

Quiz 6 - Testing knowledge about protective equipment and protective equipment

https://forms.office.com/e/f2iVZFZD6V

1. What is the basic task of a protective helmet when working at a wind farm?

a) Increases worker visibility
b) Protects against impacts and falling objects
c) It enables easier communication
d) Provides additional ventilation

2. What are the basic characteristics of protective footwear for working on wind farms?

a) Water resistance, light structure, plastic sole
b) Anti-slip sole, protective cap, anti-static properties
c) Breathable material, flexible sole, cotton insoles
d) Rubber sole, thermal insulation, sporty design

3. What type of protective gloves are used to work with electrical components?

a) Leather gloves
b) Dielectric gloves
c) Rubber gloves
d) Cloth gloves

4. What is collective protective equipment in wind farms?

a) Safety helmets and goggles
b) Safety barriers, protective nets, systems against lightning strikes
c) Insulated tools and voltage testers
d) Electrical gloves and safety shoes

5. What are the main means of protection against electric shock?

a) Reflective vests and radios
b) Insulated shoes, gloves and pads
c) Safety glasses and earplugs
d) Gas masks and respirators

Exercise:

Seminar work - Personal or collective protective equipment in wind power plants

Task: Students/Participants should write a seminar paper/PPT on personal or collective protective equipment used on wind farm construction sites.

Instructions:

- Explain the importance of safety barriers and safety nets.
- Describe how the lightning protection system on wind turbines works.
- Investigate how proper placement of signage and marking of work zones reduces the risk of accidents.
- Give examples of specific regulations and standards that regulate the use of collective protective equipment.

Additional materials for teachers

- Video materials:
- "Personal Protective Equipment for Wind Energy Workers" - display of personal protective equipment.
- "Electrical Safety in Wind Farms" - safety procedures when working with electric power components.
- "Emergency Evacuation from Wind Turbine" - demonstration of emergency evacuation from a height.

Discussion questions:

1. Why is it important to regularly check the correctness of protective equipment?
2. What protective measures must be applied when working at height?
3. How are collective protective devices installed in a wind farm?

6. PERFORMANCE OF ELECTRICAL INSTALLATIONS OF WIND POWER PLANTS

6.1. Types and basic elements of electrical installations of wind farms

Objective of the teaching unit:

Students/Participants will learn about the types and basic elements of electrical installations of wind power plants, their role in the functioning of the plant and the correct methods of installation and connection.

Key topics:

- Types of electrical installations,
- Elements of electrical installations,
- Types of conductors and cables,
- Cable accessories,
- Installation material.

Teaching methods:

- Lecture and presentation – Teachers can use pictures to represent the key elements of electrical installations.
- Demonstration of elements - Students can examine and recognize different types and basic elements of electrical installations of wind farms.

Evaluation:

- Practical tasks - Students/Participants recognize different types of cables and installation materials.

6.2. Installation of cable structures and laying of electrical installation cables

Objective of the teaching unit:

Students/Participants will learn the principles of mounting cable structures and proper laying of cables in electrical installations of wind farms, including preparation, execution and final inspection of the installation.

Key topics:

- Planning the cable route and choosing the appropriate cables,
- Types of cable constructions:
- Cable channels,
- Cable bridges and supports,
- Underground cable laying,
- Shielded and flexible cables,
- Correct execution of cable laying:
- Above ground and underground laying,
- Connecting cables in junction boxes,
- Cable marking rules,
- Ensuring mechanical protection of cables.

Teaching methods:

- Lecture and visual presentation - Use pictures and diagrams of cable routes and different methods of laying cables.
- Demonstration - Demonstration of different types of cable constructions and proper cable laying techniques.
- Practical analysis - Students recognize different types of cables and determine the correct laying methods according to the work environment.
- Discussion in groups - Students analyze the advantages and disadvantages of overhead and underground cable laying.

Evaluation:

- Practical tasks - Students recognize different types of cables and plan how to lay them.

Practical exercise:

Task: Production of cable terminations for power cables

Exercise goal:

Students/Participants will learn to properly prepare and fabricate power cable terminations, including stripping insulation, installing cable lugs and applying protective layers.

Instructions for performing the exercise:

- Before starting, the teacher should explain the different types of cable terminations and show the necessary tools (cutters, knives, crimpers).

- The teacher shows the correct way to remove the insulation, attach the conductors and the insulation of the joints, demonstrates the correct crimping of the cable lugs with a press and the application of protective layers, emphasizing the mistakes to be avoided.
- Divide the trainees into smaller groups and supervise their work, providing corrections where necessary.
- Emphasize the importance of protective equipment and safe handling of tools, especially when testing joints.
- At the end of the exercise, analyze the performed joints and discuss the challenges and possible improvements in the work.

Final check:

- Inspect the accuracy and quality of the cable terminations.
- Check the security of the connections and the proper insulation of the cables.
- Evaluation of student/participant work through practical demonstration and discussion.
- Discuss with students/participants about potential problems and ways to improve work technique.

6.3. Installation of switchboards and control panels

Objective of the teaching unit

To enable students/attendees to understand the purpose of switchboards and control panels, cabinets and counters in wind power plants, their functionality and proper assembly and connection procedures.

Key topics

- The role of switchboards and control panels in power system management,
- Types of switchboards and cabinets and their functionality,
- The procedure of assembly and connection of electrical installation elements,
- Safety aspects when mounting and maintaining panels,
- System protection against overload, short circuits and external influences.

Teaching methods

- Teaching with the use of technical drawings and schemes,
- Demonstration of installation of electrical installation elements,
- Workshops for the analysis of technical documentation,
- Group work on solving specific problems in mounting and connecting.

Evaluation

- Written test on types of panels and functionality of electrical installation elements,

Practical task:

- Simulation of installation of switchboard and control panel,
- Discussion on safety aspects during the execution of works.

Practical exercise:

Task: Installation of switchboards and/or control panels

Exercise goal:

Students/Participants will learn the correct procedures for mounting and connecting electrical installation elements in switchboards and control panels, and ensure the proper functioning of the system.

Instructions for performing the exercise:

Student/attendee preparation:

- Distribute the technical documentation to the students and explain the task.
- Explain the basic principles of operation of switchboards and control panels.
- Point out the safety measures that must be observed during the execution of the works.

Demonstration of the procedure:

- The teacher should first demonstrate practically how to mount and connect the switchboard.
- Explain each step highlighting key aspects such as power connections and safety features.

Independent work of students/participants:

- Students in smaller groups perform the assembly and connection procedure.
- The teacher monitors the work and corrects mistakes in real time.

Analysis and evaluation of work:

- After the students finish the exercise, the teacher checks the accuracy of the connections and the correctness of the placed elements.
- Together with the teacher, students analyze possible mistakes and discuss improvements.

6.4. Connection of electrical installation elements in distribution and control panels, cabinets and counters

Objective of the teaching unit

Train students/participants to properly connect electrical installation elements in distribution and control panels, cabinets and counters, in accordance with safety and technical standards.

Key topics

- Planning and preparation of electrical installations,
- Connecting protective devices,
- Connecting power and control lines,
- Connecting control devices and sensors,
- Grounding of electrical installations,
- System testing and verification.

Teaching methods

- Lecture with technical illustrations - explanation of electrical installation components and connection schemes using technical drawings and diagrams.
- Connection demonstration - presentation of the procedure for the correct connection of protection and control devices.
- Working in groups - Analysis of various technical schemes and proposing solutions for optimizing system connection, as well as presentation of improper connection problems and procedures for identifying and eliminating errors.

Evaluation

- Oral examination - questions about technical standards for connecting electrical installations and safety measures.
- Case Analysis - Discussion of potential installation problems and suggestions for improving system connectivity.
- Solution presentation - each group analyzes the resulting installation and explains the applied connection methods and safety aspects.

6.5. Installation of grounding and lightning protection of wind power plants

Objective of the teaching unit

Students/Participants will learn the principle of operation and the importance of grounding systems and lightning protection in wind farms. He will understand different types of grounding and their application in the protection of wind turbines, transformer stations and wind power grids, as well as procedures for testing the effectiveness of grounding systems.

Key topics

- The role and importance of grounding and lightning protection,
- Grounding system of wind turbines,
- Grounding of transformer stations,
- Grounding of the power grid of the wind power plant,
- Protection against overvoltage in wind farms.

Teaching methods

- Lecture with technical illustrations - explanation of the function and importance of grounding through diagrams and schemes of grounding systems.
- Demonstration - display of connection of grounding electrodes, lightning protection system and grounding check.
- Case study - analysis of concrete problems from practice related to improperly executed grounding systems.
- Group work - discussion on grounding optimization in different types of soil and climatic conditions.

Evaluation

- Oral examination - questions about types of grounding, function of grounding electrodes and surge protection.
- System testing - simulating a ground continuity test using a ground tester.
- Presentation of solutions - students/participants propose strategies for the protection of power systems in wind farms through the application of optimal grounding techniques

6.6. Measurement and control of the performance of wind turbine components

Objective of the teaching unit

Students/Participants will learn how to test and analyze the performance of key wind turbine components. He will understand the importance of continuous monitoring of operating parameters, detection of potential problems and system optimization to ensure long-term efficiency and safety of wind farms.

Key topics

- Measurement of technical parameters of wind turbines
    - Wind speed and blade performance (anemometers and wind vanes),
    - Vibration and rotor stability (vibration sensors),
    - Temperature of critical parts (bearings, generator, gearbox),
    - Generator voltage and current (measurement of electrical parameters),
    - Transmission system efficiency (calculation of torque and power),
    - Functionality of the braking system (hydraulic and mechanical brakes).
- Commissioning and testing of installed components
    - Visual inspection and checking of mechanical joints,
    - Electrical measurements (voltage, current, continuity),
    - Functional testing of the monitoring and control system,
    - Load test (stability check under maximum operating conditions),
    - Data analysis and system tuning.
- Continuous performance monitoring
    - Monitoring the operation of the turbines through the SCADA system,
    - Irregularity detection and predictive maintenance,
    - Optimization of work based on data analysis.

Teaching methods

- Lecture with visuals - Explanation of key technical parameters using diagrams and simulations.
- Demonstration - Demonstration of the operation of the software for testing vibration, temperature and electrical parameters.
- Work in groups - Analysis of data from real wind farms and discussion of the causes of performance deviations.
- Case study - Simulation of wind turbine testing using software.

Evaluation

- Oral Examination - Questions on measurement techniques and optimization of turbine performance.
- Practical task - Simulation of testing a certain technical parameter with the use of software.
- Data analysis – Interpretation of obtained measurements and making conclusions about the state of the system.
- Presentation of solutions - Group work on the proposal of a strategy for improving the operation of wind turbines based on the analyzed data.

7. EQUIPMENT MAINTENANCE AND MONITORING IN WIND POWER PLANTS

7.1. Types of maintenance and activities in the maintenance of wind power plants

Objective of the teaching unit

Students/Participants will learn different types of wind farm maintenance, their activities and importance for reliable system operation.

Key topics

- Preventive and corrective maintenance,
- Planning maintenance activities,
- The main stages of maintenance of electric power equipment,
- The effect of proper maintenance on extending the service life of the equipment,
- The role of diagnostics in detecting potential malfunctions.

Teaching methods

- Lecture - Theoretical lecture with presentation of pictures of maintenance,
- Discussion - comparative analysis of preventive and corrective maintenance.

Evaluation

- Group discussion on maintenance segments.

7.2. Preventive maintenance works of wind power plant elements

Objective of the teaching unit

Train students/participants to perform preventive maintenance of key elements of wind power plants through theoretical and practical training.

Key topics

- Visual overview of wind farm elements,
- Detection of possible damage and irregularities,
- Measurement of characteristic system parameters,
- Analysis and interpretation of measurement results,
- Safety measures when performing preventive maintenance.

Teaching methods

- Lecture - Explanation of the theoretical foundations of preventive maintenance,
- Work on technical documentation - Learning about standard review procedures,
- Demonstration - Use of inspection equipment and measuring instruments,
- Practical exercises - Performing inspections and measurements in real or simulated conditions.

Evaluation

- A discussion on the importance of preventive maintenance,

- Practical execution of reviews and analysis of results.

Practical exercises:

Task 1: Visual inspection of wind farm elements

Exercise goal:

Students/Participants will learn how to visually inspect key wind farm components to identify possible damage, irregularities and potential failures.

Instructions for performing the exercise:

Introductory preparation and explanation of the task

- Acquaint the participants with the importance of visual inspection in the maintenance of wind farms.
- Explain typical irregularities that can occur on different components (cracks, corrosion, deformations).
- Review maintenance documentation to gain insight into previously recorded problems.

Performing a review

- Divide the students/participants into teams and assign them specific parts of the wind farm to inspect.
- Use an inspection lamp and camera for a detailed examination of the condition of the foundation, tower, nacelle and blades.
- Focus on the mechanical, electrical and safety aspects of the inspection.
- Point out the importance of a systematic approach in visual inspection and documentation of findings.

Preparation of reports and analysis of findings

- Each team will prepare a report with a detailed description of the observed irregularities and recommendations for further procedures.
- Compare findings with previous reports to identify changes and potential trends in element degradation.
- Discuss possible causes of irregularities and assess the need for interventions.

Final check:

- Evaluation of accuracy and detail of inspection reports.
- Identification of potential security risks and technical problems.
- Group discussion on ways to improve the review method and interpretation of findings.

Task 2: Measurement of electrical and non-electrical quantities

Exercise goal:

Students/Participants will learn how to properly measure and analyze the electrical and non-electrical parameters of a wind farm, using various diagnostic tools.

Instructions for performing the exercise:

Introduction to measurement and safety guidelines

- Explain the purpose of measuring the key parameters of a wind power plant (voltage, current, frequency, power, temperature).
- Explain the safe way of handling measuring instruments (multimeter, anemometer, thermal imaging camera).
- Divide students/participants into teams and assign them specific measurement tasks.

Practical measurement performance

- Students will place the measuring devices at the appropriate points.
- Perform measurements of electrical parameters of the system, with accurate recording of values in the measurement protocol.
- Use a thermal imaging camera to detect potential problems with overheating components.
- Compare the readings with the standard technical specifications.

Analysis of results and interpretation of data

- Each team will analyze the measured values and notice possible deviations from the expected parameters.
- Discuss possible causes of variations in readings (changes in load, ambient temperature, system errors).
- Based on the results, students will prepare a short analysis with conclusions and recommendations for improving the system.

Final check:

- Evaluation of measurement accuracy and reliability.
- Identification of possible errors in the measurement procedure and ways to correct them.
- Discussion on the application of diagnostic methods in the real operating conditions of wind power plants.

Teachers can use additional video materials, case studies and technical documentation to give students a more realistic insight into maintenance procedures.

7.3. Corrective maintenance works of wind power plant elements

Objective of the teaching unit

To enable students/participants to identify faults and carry out corrective maintenance so that the wind farm can be quickly returned to proper working condition.

Key topics

- Corrective maintenance - definition, importance and difference from preventive maintenance.
- The most common failures - mechanical damage to the blades, electrical failures, problems with automatic steering.
- Fault diagnostics - analysis of data from the monitoring system, use of diagnostic devices.
- Troubleshooting - replacement and repair of components, testing and system commissioning.

Teaching methods

- Theoretical presentation - Overview of key concepts of corrective maintenance.
- Demonstration of working with diagnostic devices - Multimeter, oscilloscope, thermal imaging camera.
- Practical exercise - Fault diagnosis.

Evaluation

- Practical exercise - Fault diagnosis.
- Analysis of tasks - Assessment of correctness of diagnostics and proposed solutions.
- Discussion - Suggestions for improving maintenance and preventing breakdowns.

Practical exercise:

Task: Fault diagnosis

This practical exercise can be carried out in cooperation with the local company that maintains the wind farm.

Exercise goal

Students/Participants will learn how to use diagnostic devices to identify faults, analyze the causes of problems and propose appropriate solutions.

Instructions for performing the exercise:

- Preparation of students/participants: Provide access to technical documentation and explain the basic methods of fault diagnosis. Demonstrate operation of diagnostic devices, including multimeter and oscilloscope.
- Data collection: Students will analyze documentation and records of previous failures, identify system errors and alarm signals.
- Use of diagnostic devices: Use a multimeter to measure voltage, current and resistance, and an oscilloscope for signal analysis and interference detection.
- Analysis of the results: Students will compare the measured values with the nominal parameters of the system, identify the cause of the problem and suggest possible remedial measures.
- Failure simulation: Organize controlled conditions in which students will practically work on problem diagnosis and apply error analysis methods.
- Final Analysis: After the exercise, organize a discussion of the results and consider alternative solutions for corrective maintenance.

Final check

- Fault Analysis – Evaluate the accuracy of fault identification and its causes.
- Use of diagnostic devices - Check the correctness of the use of the instruments and the accuracy of the readings.
- Documenting the results - View a report with a description of the failure, analysis and solution proposal.
- Discussion and Conclusions – Consider alternative approaches to problem solving and suggest possible improvements in the diagnostic process.

7.4. Maintenance works of electrical installations of wind power plants

Objective of the teaching unit:

To train students/participants in understanding the importance and methods of maintaining electrical installations in wind farms, including preventive and corrective measures.

Key topics

- Preventive maintenance of electrical installations,
- Maintenance of the grounding system and lightning protection,
- Inspection and testing of the distribution cabinet and mains connection,
- Insulation and grounding resistance measurement,
- Eliminating faults in electrical installations.

Teaching methods

- Theoretical lecture - Explanation of key maintenance procedures and safety standards.
- Practical exercise - Students conduct a visual inspection of electrical installation elements.
- Case study analysis - Overview of real examples of failures and methods of their elimination.

Evaluation

- Practical check - Students will inspect and test electrical installations under the supervision of the teacher.
- Discussion of findings - Analysis of possible problems and suggestions for improving maintenance procedures.
- Quiz on equipment maintenance in wind farms.

Practical exercise:

Task: Visual inspection of electrical installation elements

Exercise goal:

Students/Participants will learn how to perform a visual inspection of the electrical installations of a wind farm, to identify potential faults and propose measures to eliminate the problem.

Instructions for execution

Preparing for inspection

- Explain to students the importance of visual inspection as the first stage of diagnosing problems in power systems.
- Review the technical documentation so that students understand the function of the reviewed elements.
- Provide protective equipment and demonstrate proper use of inspection tools.

Visual inspection of installations

- Guide students/participants through the procedure of inspecting distribution cabinets, cables and protective devices.
- Point out signs of overheating, corrosion, mechanical damage and bad connections.

- Encourage students/attendees to use an inspection lamp for hard-to-reach areas and to document observations.

Documenting findings and analysis

- Students/Participants take photos and write down observed irregularities in the inspection report.
- Encourage students/attendees to analyze possible causes of problems and propose corrective measures.
- Organize a discussion on how preventive maintenance can prevent breakdowns.

Final check

- Review inspection reports and assess the accuracy of student/participant assessments.
- Discuss best practices in electrical maintenance and possible inspection improvements.
- Connect the results of the exercise with realistic wind farm maintenance scenarios.

Quiz 7: Maintenance of equipment in wind farms

https://forms.office.com/e/NHFUEUZkiU

1. What is the main purpose of preventive maintenance of wind farms?

a) Repair of defects after their occurrence
b) Preventing breakdowns and extending the life of equipment
c) Increase in energy production without maintenance
d) Reduction of electricity costs

2. What are the basic activities of preventive maintenance of wind farms?

a) Replacement of worn parts, lubrication, visual inspection and measurement of electrical quantities
b) Exclusive repair of damaged systems
c) Just cleaning and replacing the filter
d) Increasing rotor speed to optimize operation

3. What is the primary goal of corrective maintenance?

a) Detecting potential problems before they cause failure
b) Removal of detected faults and restoration of the system to a functional state
c) Reduction of wind turbine operating costs
d) Increase in electricity generation capacity

4. What is checked during the visual inspection of the elements of the wind farm?

a) The color of the wind turbine blades
b) Existence of cracks, corrosion, deformation and overheating
c) Wind turbine operating frequency
d) Wind strength at the location

5. What device is used to measure grounding resistance?

a) With a digital multimeter
b) Megaohmmeter
c) Thermal imaging camera
d) With an oscilloscope

6. What is the main purpose of the lightning protection system in wind farms?

a) Noise reduction during turbine operation
b) Surge prevention and lightning protection
c) Increasing the speed of the wind turbine
d) Voltage regulation in electrical installations

7. What are the basic methods of diagnosing faults in wind power plants?

a) Visual inspection, use of diagnostic devices and data analysis of the surveillance system
a) Physical inspection of components only
b) Only consultation with the turbine manufacturer
c) Only use of thermal imaging cameras

8. Which of the sitting factors can be a sign of problems with electrical installations?

a) Low cable temperature
b) The presence of corrosion at the joints and overheating of the connections
c) Absence of current load
d) Stable operation of the system without errors

9. What measures should be taken after eliminating the fault at the wind power plant?

a) Return the system to work without additional checks
b) Perform functional testing and testing of all key elements
c) Report a fault and wait for further instructions
d) Remove all protective means to improve work efficiency

10. Why are thermal imaging cameras used in the maintenance of wind farms?

a) For the detection of temperature anomalies on electrical components
b) For measuring wind speed
c) To check the rotor's integrity
d) To check the oil level in the turbine

Additional recommendations for teachers:

- Use of video materials - It is recommended to use videos that show electrical installation maintenance procedures in real conditions.
- Site Research - It is recommended to research the proposed sites that provide a more detailed description of the equipment maintenance procedures in wind farms
- Practical work in cooperation with industry - If possible, organize a visit to a local company that maintains wind farms so that students can see the application of theoretical knowledge in practice.
- Case Study Analysis - Students can work on analyzing specific failures and propose solutions based on the principles learned.

7.5. Collection, processing and storage of data in wind power plants

It is suggested that this teaching unit be implemented in real conditions during a visit to a wind farm.

Objective of the teaching unit

Students will gain knowledge about the importance of data collection, processing and storage in wind farms, types of monitoring and control systems, as well as the role of digitization and analytical software in optimizing the operation and maintenance of wind turbines.

Key topics

- The role and importance of data collection in wind farms,
- Key parameter monitoring systems and their function,
- Types of sensors and measuring devices in wind farms,
- Communication and network equipment,
- SCADA system - management and supervision of wind farms,
- Data storage and analysis systems,
- Security systems and cyber data protection.

Teaching methods

- Lecture with technical illustrations - Explanation of the role of data in the operation of wind farms.
- Demonstration - Demonstration of SCADA system operation and data management software.
- Case study - Analysis of real data from a wind farm and discussion on optimization of operation.

Evaluation

- Oral examination - Questions on the key components of the surveillance and data storage system.
- Student/participant report - Each group prepares a report on the completed visit to the wind farm.

8. CONCLUSION AND RECOMMENDATIONS

The development of renewable energy sources brings new challenges in the education of professional staff, especially in the field of installation and maintenance of electrical power equipment in wind farms. This manual provides teachers with methodological guidelines, teaching strategies and practical recommendations that enable effective teaching and professional training of students/participants.

Considering the complexity of working in wind farms and the specific challenges that accompany their installation and maintenance, the manual is structured to include key technical aspects, safety measures and best practices in preventive and corrective maintenance. Special attention is paid to occupational safety and environmental protection, with the aim of raising awareness of the importance of safety and responsible management of resources. As an important recommendation, the authors emphasize the need for cooperation with local associations and companies in order to improve the knowledge and practice of students/participants.

However, conducting practical classes in real conditions represents a significant challenge due to limited material resources, specific equipment and necessary safety measures. Installation and maintenance of power equipment in wind farms require work at height, work with high voltages and extreme weather conditions, which further complicates the organization of practical classes in school workshops and industrial environments. The limited availability of work locations and the complexity of simulating real working conditions impose a need for alternative training methods.

Therefore, the authors strongly recommend the implementation of VR (Virtual Reality) and AR (Augmented Reality) simulations as a key solution for overcoming the limitations of practical training. These technologies allow students to acquire practical skills, practice key processes and prepare for field work in a completely safe and controlled environment. Integrating VR and AR simulations into education can significantly improve the quality of teaching, providing a realistic and interactive experience without risking student safety.

Practical exercises are shown in detail, step by step, emphasizing the necessity of adequate material conditions and equipment. The authors recommend that teachers, wherever possible, organize cooperation with local companies that work on the construction and maintenance of wind farms, so that students can gain additional experience through industrial practice. In situations where this is not possible, VR and AR simulations represent the optimal solution for acquiring practical competencies. In addition to visits to plants, thematic events can be organized with the aim of presenting student works or smaller projects on the topic of using renewable sources of electricity.

In order to better connect theoretical knowledge with practical skills, the manual includes open-source video materials that allow users to do additional research through visual representations of key technical processes. Also, the manual contains a large number of quizzes created in Microsoft Forms format, which teachers can modify and adapt to the needs of their students/participants, thus training can be further personalized and optimized.

The labor market shows an increasing need for qualified experts in the renewable energy sector, especially in the field of wind farms, where further growth in capacity and employment is expected. Through a systematic approach to education and continuous professional development, teachers can play a key role in preparing future installers and technicians for this dynamic and promising industry.

Recommendations for teachers

1. Improve learning methods through VR and AR technologies - The implementation of virtual simulations allows students to practice key operations in a controlled environment and prepare to work in real conditions.
2. Connect theory and practice - By using video materials, simulations and digital tools, enable students to better understand the complexity of power equipment in wind farms.
3. Encourage research work and innovation - Through project assignments and seminars, students/students should be encouraged to research new technologies in the field of wind energy.
4. Emphasize safety at work - Students must become aware of the importance of safety procedures and use personal protective equipment at all stages of training.
5. Use available resources – Teachers can adapt and use quizzes from the handbook to test student/participant knowledge and motivate active learning.
6. Develop cooperation with industry - Wherever possible, organize visits to wind farms, cooperation with companies and engagement of experts from practice.
7. Promote sustainable development and recycling - The authors also referred to the problems of recycling electrical power equipment in wind farms, and it is necessary to educate students/attendees about the importance of proper waste management and recycling processes in this sector.

The manual is designed so that it can serve as teaching material in formal education in secondary schools, but also as a resource for professional courses and training in the field of wind power plants. Its application enables teachers to plan and implement lessons with quality, improve the competences of students/participants and contribute to the development of professional staff in the field of renewable energy sources.

This manual is not only an educational tool, but also a resource for improving the teaching process through modern learning methods and digital simulations. The implementation of VR and AR technologies can significantly improve the training process, allowing students/participants to acquire practical skills necessary for the labor market in an innovative way.

9. MATERIAL CONDITIONS AND EQUIPMENT

SPACE, OUTLINE LIST OF EQUIPMENT AND TEACHING MATERIALS	FORMAL EDUCATION pieces	INFORMAL EDUCATION pieces
Classroom for theoretical teaching	1	1
Laboratory for practical teaching	1	1
A computer with dedicated software installed for monitoring classes, carrying out exercises and checking acquired knowledge	11	4
Analog measuring instruments (voltmeter, ammeter, ohmmeter, multimeter, wattmeter, etc.)	4	3
Digital measuring instruments (multimeter, voltmeter, ammeter, clamp meter, wattmeter, frequency meter, oscilloscope, network analyzer, etc.)	4	3
Measuring instruments for measuring non-electric quantities (pyranometer, digital thermometer, temperature sensors, vibration sensors, anemometer, weather vane, inclinometer, thermal imaging camera, network analyzer, etc.)	5	3
DC voltage source, function generator, transformer, switches, fuses, relays, etc.	5	3
Electrical installation equipment (switches, disconnectors, contactors, fuses, surge arresters, relays, sensors, control and signaling devices, busbars, insulators, connection terminals, distribution cabinets, distribution box, mounting box, rails for elements in the distribution board, differential current protection device, etc.)	10	3
A set of tools for electricians (screwdrivers, pliers for removing insulation, pliers, cutters, soldering iron, etc.)	10	3
Tools for marking and processing materials (stick compass, devices for parallel delineation, scissors, cutters, hammer, keys, saws, files for sheet metal and wood, pliers, sander, drill, bonsek, etc.)	10	3
Tools: insulating pliers, compression pliers, wire cutters, metal saws, screwdrivers, wrenches, torque wrenches, files, hammers, locksmith tools, hydraulic tools (hydraulic presses, guns, etc.), manual lifting equipment, scissors and knives for cutting insulation material, sheet metal shears, saws, soldering tool, sheet metal bending tool, profile bending tool, punching tool, cutting tool, tool for cutting, threading tool, measuring and control tool, welding tool and accessories, spirit level, etc.	5	3
Grounding elements: structural elements (earthing devices, grounding busbars, connecting lines), connecting elements (shoes, feet, clamps for connecting and fixing)	5	3
Elements of lightning protection: arresters (lightning rods), drains (galvanized tape), grounding device, measuring connection, connecting elements (clamps, screws and nuts, lugs, ties, etc.)	5	3
Material: wiring conductors and cables, cable heads, cable joints, clamps, connectors, splitters, insulating tapes and other insulating material, PV pipes and boxes, lubricants, rust removers, corrosion protection agents (anti-corrosion paints, coatings and mastics), sealing materials, screws and nuts, marking and signaling material, construction material, etc.	5	3
Set of personal protective equipment: safety helmet, safety belt and lanyards (system for working at height), protective gloves, protective clothing and footwear, antiphons (noise protection) and safety glasses, masks with anti-evaporation filters	10	3
First aid kits, first aid practice kits	5	3
Fire extinguishers, for demonstration and training in case of fire	5	3
Laboratory model of a wind power plant (simulator) with technical documentation (Festo Didactic Wind turbine Simulator or similar)	1	1

SET OF EQUIPMENT FOR MONITORING AND DATA MANAGEMENT IN WIND POWER PLANTS	
1. Control and communication devices	• *Data Manager*(data management module) • Communication cable (optical or copper) • Server (local or cloud platform) • Wind farm management software • SCADA system (Supervisory Control and Data Acquisition)
2. Sensors and measuring devices	• Anemometer (wind speed measurement) • Wind vane (Wind vane, wind direction) • Temperature sensors • Vibration sensors • Humidity and pressure sensors
3. Communication and network equipment	• *Industrial Ethernet Switch* • 4G/5G or satellite modems • Optical or copper communication cables • Wireless communication modules (Wi-Fi, Zigbee, etc.)
4. Data storage and analysis systems	• *Data Logger*(data collection from sensors) • Local servers (fast data processing) • *Cloud-based*platforms (long-term storage and analytics)
5. Systems for environmental monitoring	• Noise level monitoring systems • Sensors for monitoring the activity of wild animals • Monitoring of habitat changes
6. Safety and protective equipment	• UPS systems (Uninterruptible Power Supply) • *Firewall*devices (network protection against cyber attacks) • VPN systems (secure remote access) • Antivirus and IDS/IPS systems (security monitoring)
7. Cameras and security systems	• Thermal cameras (overheating detection) • IP surveillance cameras (turbine protection and monitoring) • Drones with cameras and sensors (inspection of hard-to-reach parts)

Literature and used sources

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Organizations and standardization sources:

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- Global Wind Energy Council (GWEC) – www.gwec.net
- IEEE Power & Energy Society - www.ieee-pes.org
- International Electrotechnical Commission (IEC) – www.iec.ch
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- https://ieeexplore.ieee.org/document/8467935
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- https://www.engie.com/en/activities/renewable-energies/wind-energy/recycling-wind-turbines

Links to suggested video material

- https://www.youtube.com/watch?v=8sPp8G8a48E
- https://www.youtube.com/watch?v=nA9oC--tq50
- https://www.youtube.com/watch?v=qSWm_nprfqE
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