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Manual for teachers

for installing and maintaining solar photovoltaic systems

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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 created to support secondary school teachers and adult education program lecturers who teach in the field of renewable electricity 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/participants "Installation and maintenance of solar photovoltaic systems", 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 solar photovoltaic systems, 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.

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

- Application of modern teaching methods to increase the engagement of students/attendees.
- Organization of individual and team tasks in order to simulate real working conditions.

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 the 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 participants to actively follow the class. Through questions, suggestions and exchange of opinions on topics, 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 minimize disruption of the work process and enable the active involvement of each student/participant in practical work. Part of the practical teaching is carried out 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 teaching is carried out in cooperation with local companies that perform and maintain solar photovoltaic systems.

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. Seminar 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 plays a key role in ensuring the quality of training and developing the competencies required to work in solar photovoltaic systems. 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/participants to delve deeper into specific topics related to the installation, maintenance and safety of solar PV systems and to 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 suggested video material, quizzes and topics for seminar papers, the teacher can at his own discretion propose video material, create suitable quizzes, edit existing quizzes, create tests and assign topics for seminar papers.

All elements of teaching should be aimed at encouraging problem-based content of a practical nature, so that participants independently come to conclusions when solving problems. Maximally applying and connecting theoretical knowledge to solve practical tasks and problems, participants will strengthen their ability to think independently. The goal is to acquire theoretical knowledge and skills that enable 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. Importance and application of solar photovoltaic systems

Guidelines for teachers:

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

- A basic understanding of the importance of using solar photovoltaic systems (SFNS).
- Market analysisof work and employment opportunities in the sector of renewable energy sources.

Objective of the teaching unit:

- Acquaint students/participants with the importance of solar photovoltaic systems as a renewable source, their ecological and economic advantages and the possibilities of application in the power sector.

Methodological recommendations for teachers:

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

Evaluation:

- Critical Analysis - Students/Participants can discuss challenges related to the application of solar photovoltaic systems (eg environmental impact, economic profitability, dependence on weather conditions).
- End-of-class Q&A - Summarize key information through discussion and check student/attendee understanding by asking questions about the practical application of solar PVsystem.

1.3. Manual structure

The manual is organized in such a way that it fully follows the content of the manual for students/training participants. It consists of eight chapters that deal in detail with the key aspects of working with power equipment in solar photovoltaic systems. 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 - Overview of different forms of renewable energy sources, with a focus on solar energy.

Chapter 3, Safety at work and environmental protection - Safety measures and environmental protection when working on power equipment in solar photovoltaic systems.

Chapter 4, Energy from the sun - Basic characteristics of solar photovoltaic systems and their application in the power sector.

Chapter 5, Construction of solar photovoltaic systems - Basic terms and types of solar systems, their characteristics and division criteria. The structure of solar photovoltaic systems, the key elements of the system, as well as the material, tools and equipment necessary for the construction and maintenance of these energy plants are covered.

Chapter 6,Performing electrical installations of solar photovoltaic systems - Procedures for performing electrical installations in solar photovoltaic systems, including a brief description of the installation of grounding and lightning protection.

Chapter 7, Operation and maintenance of solar photovoltaic systems - Preventive and corrective methods of maintenance of power systems and procedures for their implementation. Consideration of operating costs, payback period and potential income.

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

A useful addition to the manual is the main wiring project of the small solar photovoltaic system "MSE Sunstream 3" 49.4 kWp by Zdravko Perić, which can be found at the linkhttps://www.erisee.org/wp-content/uploads/2025/04/04-MSE-SUNSTREAM-PDF-Protect. pdf. This project can serve as an example for teachers and students/students, on the basis of which a case study of a small solar PV system can be done. The authors of the manual would like to thank Zdravko Perić for the permission to use his solar photovoltaic system project.

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. It is necessary to 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

- 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
- Hydropower and hydropower plants
- Sea and ocean energy
- Geothermal energy and its applications
- Biomass and biomass power plants
- Wind energy and wind farms
- Advantages and challengesapplication of renewable energy sources

Teaching methods

- **Lecture and presentation**- Teachers explain the basic terms and principles of operation of certain types of power plants, using illustrations, graphs and video materials.
- **Working in groups**- Students/Participants analyze different energy sources, their advantages and challenges.
- **Discussion and debate**- Arguing the advantages and challenges of different energy sources in the context of sustainable development.

Evaluation

- **Quiz with key terms**– Quiz with multiple choice questions.
- **Independent task**- Researching local or global renewable energy sources and making a short presentation about their role in the energy system.
- **Research paper/PPT presentation**- Topic: Analysis of energy plants in the region and the world
- **Critical analysis**- Discussion on the challenges and possibilities of applying renewable energy sources in modern societies.

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

Exercise goal:

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

Instructions for execution:

1. Introduction

- Explain the basic types of energy plants
- Discuss their significancefor the local community and sustainable development.

2. Research

- Students/Participants collect data on selected power plants (location, capacity, technology).

3. Analysis

- Assess the contribution of power plants in energy supply.
- Consider the economicbenefits and impact on the environment.

4. Presentation of results

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

Evaluation of research work:

- Creativity of presentation – Is the data clearly presented in a written paper or visual presentation?
- Discussion and conclusions - Do the students/participants present the benefits and challenges of energy plants in an argumentative mannerfrom renewable sources in your region and the world?

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 perform 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) Underground water 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 strength
b) Position of the panel in relation to the Sun
c) The depth of the ground on which they are placed
d) Amount of precipitation

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 underground water
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 hydropower plants
c) Reversible hydropower 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 CO_2 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

3. SAFETY AT WORK AND PROTECTION OF THE ENVIRONMENT

3.1. Possible hazards to the health and safety of workers when working on solar photovoltaic systems

Objective of the teaching unit:

Acquaint students/participants with the risks of working in solar photovoltaic systems 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 with live parts, step voltage, electric arc),
- Presence of dangerous substances and chemicals,
- Possibility of fireand explosion.

Teaching methods:

- Lecture on 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 onrecognizing risks to the health and safety of workers.

Evaluation:

- Analysis of behavior in simulated dangerous situations.

Videos:

Step and touch voltage

https://www.youtube.com/watch?v=8sPp8G8a48E

3.2. Application of safety and protection measures at work when performing work on solar photovoltaic systems

Objective of the teaching unit:

Acquaint students/participants with safety and protection measures at work when performing work on solar photovoltaic systems, as well as with the proper use of personal and collective protective equipment.

Key topics:

- Categories of work according to the presence of voltage (no-voltage condition, work near voltage, work under voltage),
- Basic principles of protection against electric shock and precautions,
- Personal protective equipment (helmets, safety glasses, visors, gloves, protective clothing, safety belts),
- Collective protective means (isolation barriers, protective partitions, warning signs),
- Five golden rules of safety when working on solar photovoltaic systems,
- Checking the correctness of the protectiveequipment before starting work,

Teaching methods:

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

Evaluation:

- Questions and answers at the end of the class - 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 solar photovoltaic systems.

3.3. Implementation of safety measures and personal protection measures when working at height in solar photovoltaic systems

Objective of the teaching unit:

Acquaint students/participants with safety and protection measures when working at height in solar photovoltaic systems, as well as with the proper use of personal and collective protective equipment.

Key topics:

- Specifics of workplaces at height (roofs of buildings, access platforms, panel supports).
- Identification of factors of the working environment (weather conditions, stability of the base, safety of access).
- Personal protective equipment for working at height (helmets, safety belts, anchor points, ropes).
- Collective protection measures (protective fences, barriers, stable platforms).
- Evacuation procedures and emergency responses in the event of an accident.
- Communication between workers for coordination and safe execution of works.

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.
- Work simulationsituations using models and safety equipment.

Evaluation:

- Quiz - Application of safety and protection measures at work when performing work on solar photovoltaic systems.
- Analysis of real accidents and discussion of preventive measures.
- Practical verification of knowledge through implementationassigned practical exercises.

Practical exercises:

Task 1: Evacuation simulation

Exercise goal:

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:

- To ensurea safe environment to perform an evacuation simulation.
- Install anchor points and ensure all seat belts and carabiners are in working order.
- Divide roles in the team (person for communication, person for checking equipment, person for carrying out evacuation).

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 you practiceperformed in controlled and safe conditions.

Evaluation and final check:

- Analyze the performance of the exercise and identify possible errors.
- 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

Objective of the exercise:

Participants will practice emergency rescue procedures from a height, including the proper use of a safety net, a casualty lowering system, and team coordination during an 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 safety netting, ropes, pulleys and carabiner clips to ensure proper 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 when performing work on solar photovoltaic systems

https://forms.office.com/e/J2vYyMiPED

1. What are the main risks when performing work at height on solar photovoltaic systems?

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

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) Standard of protection

4. Induced voltage can be dangerous when working on the electrical installations of the solar photovoltaic system.

a) Correct
b) Incorrect

5. Which protective means belong to personal protective equipment when working on solar photovoltaic systems?

a) Protective 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 providing assistance to a person under electric shock in solar photovoltaic systems?

a) Check breathing and pulse
b) Power off
c) Direct withdrawal of the victim
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:

Working at height

https://www.youtube.com/watch?v=FqEOVrBnE58

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 solar photovoltaic systems on the environment.

Objective of the teaching unit

Acquaint students/participants with environmental challenges and measures to reduce the negative impact of solar photovoltaic systems on the environment. Develop awareness of the importance of proper planning, waste management and recycling of solar panels in order to achieve sustainable development.

Key topics

- Impact of solar photovoltaic systems on soil, biodiversity and ecosystems.
- Optical interference and impact on birds and other species.
- Noise and electromagnetic interference.
- Proper planning of solar farm locations.
- Panel reflection reduction technologies.
- Sustainable management of solar waste and recycling of solar panels.
- Regulation and examples of good practice in the world.

Teaching methods

- Lecture and discussion - Explanation of environmental challenges and presentation of examples of good practice from around the world.
- Case study - Analysis of concrete examples (eg recycling application in the EU, solar farms on industrial sites).
- Group work - Students/Participants create a plan for an environmentally sustainable solar power plant.
- Simulation - Life cycle analysis of solar panels and discussion of end-of-life disposal options.
- Practical exercises - Waste management and application of protective equipment when implementing environmental protection measures.

Evaluation:

- Independent task - researching ways of recycling parts of solar photovoltaic systems in different countries and analyzing their sustainability.
- Essay or short term paper - students/participants can write on the topic: How technologies reduce the negative environmental effects of solar photovoltaic systems?
- Critical analysis - a discussion of the balance between the benefits of solar PV systems 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 solar photovoltaic systems

Exercise goal:

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

Instructions for performing the exercise:

- Before starting the exercise, hold a short theoretical lecture on the types of waste in the solar 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 solar 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 solar photovoltaic power plant, 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 students/participants into teams and task them with a simulated hazardous waste handling scenario, 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 on challenges and potential improvements in environmental protection when working in solar photovoltaic systems.

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. SUN ENERGY

Objective of the teaching unit

Acquaint students/participants with the basic characteristics of solar energy, types of solar radiation, its parameters and measurement methods. Develop an understanding of the influence of geographical and meteorological factors on the utilization of solar energy in photovoltaic systems.

Key topics

- Basic characteristics of solar energy,
- Types of solar radiation and their role in solar systems,
- Solar radiation parameters (intensity, spectral composition, solar constant),
- Map of solar radiation by region (site for obtaining precise data on solar radiation:https://globalsolaratlas.info/map),
- Factors affecting variations in solar radiation,
- Solar radiation measurement methods and instruments.

Teaching methods

- Lecture and discussion - Explanation of basic terms and factors that affect the use of solar energy.
- Group work - Simulation of solar system planning using GIS tools.

Evaluation

- Critical Analysis - Discussion on the Influential Factors of Solar Radiation.

4.1. Solar energy systems and their application

Objective of the teaching unit

Acquaint students/participants with the basic types of solar energy systems, their working principles and application.

4.2. Solar collector systems (SKS)

Objective of the teaching unit

Acquaint students/participants with the principle of operation, components and types of solar collector systems. Explain their application in different sectors, the advantages and challenges of implementation, and the importance of using solar thermal energy for a sustainable future.

Key topics

- Basic principles of operation of solar collector systems,
- Components of solar collector systems and their importance,
- Types of solar collectors and their characteristics,
- Application of solar collector systems in different sectors,
- Advantages and challenges of solar collector systems.

Teaching methods

- **Lecture and discussion**- Explanation of the operation and components of solar collector systems.
- **Practical demonstration using video material**- Display of collector models and their efficiency in operation.
- **Case study**- Research on the application of solar collectors in industry and households.

Evaluation

- **Independent task**- Research on the application of solar collector systems in industry and households.
- **Critical analysis**- Discussion on ecological and economic aspects of solar thermal energy.

4.3. Concentrated solar systems (solar thermal power plants)

Objective of the teaching unit

To acquaint students/participants with the working principles of concentrated solar systems, their technologies and application in the production of electricity. Explain the advantages and challenges of this technology, and the role of solar thermal power plants in the energy transition.

Key topics

- Basic principles of operation of concentrated solar systems (CSP),
- Types of CSP technologies: parabolic trough collectors, linear Fresnel collectors, solar panels, solar towers,
- Advantages and disadvantages of CSP systems.

Teaching methods

- **Lecture and discussion**- Explanation of the operation and key components of the CSP system.
- **Case study**- Analysis of examples of solar thermal power plants around the world.
- **Video demonstration**- Display of operation of heliostats and receiving towers.

Evaluation

- **Quiz with key terms**– Quiz with multiple choice questions about SKS and CSP technologies and their applications.
- **Critical analysis**– advantages and challenges of CSP systems in different climatic conditions.

Quiz 3: SKS and CSP technologies and their applications

https://forms.office.com/e/K8RJQZTQPU

1. What is the basic purpose of solar collector systems (SKS)?

a) Production of electricity
b) Heating the heat transfer fluid
c) Direct conversion of sunlight into electricity
d) Energy storage for later use

2. Which of the seating components is NOT part of a solar collector system?

a) Solar collector
b) Circulation pump
c) Electricity generator
d) Heat exchanger

3. Which type of solar collectors has the best insulation and the least heat loss?

a) Flat plate collectors
b) Vacuum tube collectors
c) Concentration collectors
d) Linear Fresnel collectors

4. What is the main disadvantage of solar collector systems?

a) High maintenance costs
b) Inability to store energy
c) High CO2 emissions
d) Short lifespan

5. Which component enables heat storage in solar-thermal systems?

a) Circulation pump
b) Heat exchanger
c) Accumulation tank
d) Measuring instruments

6. What principle of operation do concentrated solar systems (CSP) use?

a) Direct conversion of sunlight into electricity
b) Collection of solar radiation using photovoltaic cells
c) Focusing the Sun's rays to heat the working fluid
d) Transformation of kinetic wind energy into electrical energy

7. What is the main advantage of CSP systems compared to photovoltaic systems?

a) Lower installation costs
b) The possibility of storing energy for the production of electricity at night
c) Smaller area required for installation
d) Direct conversion of light into electrical energy

8. Which CSP system technology uses heliostats to reflect the Sun's energy to a central receiver?

a) Parabolic collectors
b) Linear Fresnel collectors
c) Solar towers
d) Solar dishes

9. What is the main purpose of parabolic trough collectors in CSP systems?

a) Direct conversion of solar energy into electrical energy

b) Focusing the Sun's rays on the pipe with the working fluid

c) Converting mechanical energy into electrical energy

d) Cooling of the working fluid in the system

10. What are the main disadvantages of the CSP system?

a) Low efficiency and low reliability

b) High initial costs and dependence on direct solar radiation

c) Inability to store energy and low resistance to weather conditions

d) High emission of greenhouse gases

Quiz 4: Solar Collector Systems (SCS) and Concentrated Solar Systems (CSP)

https://forms.office.com/e/6KyGAFYrMc

1. What is the main purpose of solar collector systems (SCS)?

a) Production of electricity
b) Storage of sunlight
c) Heating fluids for various applications
d) Rainwater harvesting

2. What is the basic principle of operation of solar collector systems?

a) Direct conversion of solar energy into electricity
b) Collecting solar energy and storing it in batteries
c) Absorption of solar energy and heat transfer to the working fluid
d) Using solar panels for steam production

3. Which type of collector provides the highest efficiency due to better heat retention?

a) Flat plate collectors
b) Vacuum tube collectors
c) Concentration collectors
d) Solar mirrors

4. Which of the following fluids can be used as a working fluid in SKS systems?

a) Electric current
b) Thermal oil
c) Hydrogen
d) Oxygen

5. Where are solar collector systems most often used?

a) In thermal power plants
b) In hydroelectric power plants
c) In water heating for households, industry and district heating
d) In cooling systems

6. What are the main disadvantages of solar collector systems?

a) High initial costs and dependence on solar radiation
b) Impossibility of working at low temperatures
c) Unreliability in long-term work
d) High CO_2 emissions

7. What technology is used in concentrated solar power systems (CSP)?

a) Photovoltaic cells
b) Thermal collectors with ordinary glass
c) Optical devices such as mirrors and lenses for focusing solar energy
d) Electrical transformers

8. Which type of CSP system uses heliostats to focus sunlight onto a central receiver?

a) Parabolic collectors
b) Linear Fresnel collectors
c) Solar dishes
d) Solar towers

9. What is the main advantage of CSP systems compared to photovoltaic systems?

a) Possibility of storing heat for continuous production of electricity
b) Cheaper installation and maintenance
c) Greater resistance to weather conditions
d) Smaller required installation area

10. Why are CSP systems more suitable for industrial use than photovoltaic systems?

a) They take up less space than photovoltaic panels
b) They can reach high temperatures suitable for industrial processes
c) They do not require maintenance
d) They do not depend on sunlight

4.4. Basic components of solar photovoltaic systems

Objective of the teaching unit

Familiarize students/attendees with the basic components of solar photovoltaic systems, including photovoltaic cells and panels, their structure, principle of operation and electrical characteristics. Develop an understanding of the different types of photovoltaic cells and panels and their impact on the efficiency of solar systems.

Key topics

- The structure and principle of operation of photovoltaic cells,
- Types of photovoltaic cells and their efficiency,
- Electrical characteristics of photovoltaic cells and their application,
- Formation of photovoltaic panels and ways of connecting cells,
- Electrical characteristics of photovoltaic panels and technical specifications.

Teaching methods

- Lecture and discussion - Explanation of the basic components of solar photovoltaic systems and the principles of operation.
- Practical demonstration - Analysis of the electrical characteristics of photovoltaic cells and panels.
- Experimental analysis - Measurement of IV characteristics of photovoltaic cells.
- Group work - Designing the optimal solar system with the selection of appropriate photovoltaic components.

Evaluation

- Independent task - Investigating the advantages and disadvantages of different types of photovoltaic cells and panels.
- Work in groups - Discussion on the formation of photovoltaic panels and analysis of electrical characteristics

Videos:

Solar photovoltaic panel structure

https://www.youtube.com/watch?v=TZTUefOjNl8

4.5. Characteristics and types of solar photovoltaic systems

Objective of the teaching unit

To acquaint students/participants with the basic characteristics of solar photovoltaic systems, their classification and factors that affect their efficiency. Develop an understanding of the importance of energy storage and integration into smart power grids.

Key topics

- Categories of solar photovoltaic systems according to power and application
- Basic characteristics of solar photovoltaic systems

Teaching methods

- Lecture and discussion - Explanation of the key characteristics of solar photovoltaic systems and the impact on power grids.
- Evaluation
- Critical Analysis - Discussion on the viability of solar photovoltaic systems and the possibilities of improving the technology.

4.5.1. Division of solar photovoltaic systems according to different criteria

Objective of the teaching unit

Acquaint the students/participants with the different classification criteria of solar photovoltaic systems. Develop an understanding of their technical and operational characteristics, including mode of operation, installation location, system size and type of PV cells used.

Key topics

- Division according to work autonomy (independent, network, hybrid),
- Division by location (rooftop, ground, floating, mobile),
- Division by system size (micro, small, medium, large power plants),
- Division according to panel technology (monocrystalline, polycrystalline, thin-film, organic, perovskite).

Teaching methods

- Lecture and discussion - Overview of the basic criteria for dividing solar photovoltaic systems.
- Group work - Students/Participants compare solar photovoltaic systems according to the given classification criteria.

Evaluation

- End-of-class Q&A – Summarize key information through discussion and check student/attendee understanding by asking questions about the classification of solar PV systems

4.5.1.1. Independentand (Off-Grid) solar photovoltaic systems

Objective of the teaching unit

Acquaint students/participants with the working principles, structure and components of independent (off-grid) solar photovoltaic systems. Develop an understanding of different types of off-grid systems and their applications in different environments.

Key topics

- Classification of off-grid solar photovoltaic systems,
- The structure and principle of operation of the off-grid system,
- Basic components of the system (DC and AC components, battery system, grounding),
- Displays and schematic diagrams for understanding energy flows.

Teaching methods

- Lecture and discussion - Explanation of the principles of operation and application of the off-grid system.
- Group work - Investigation of the impact of battery capacity on the operation of off-grid systems.

Evaluation

- Discussion - about the impact of battery capacity on the operation of off-grid solar systems.
- Critical Analysis - Discussion on the operation and application of off-grid solar systems.

Videos:

Principle of operation of off-grid solar photovoltaic systems

https://www.youtube.com/watch?v=j_4rJS35GF4

4.5.1.2. Network (On-Grid) solar photovoltaic systems

Objective of the teaching unit

Acquaint students/participants with the working principle, structure and components of on-grid solar photovoltaic systems. Develop an understanding of the advantages and limitations of these systems in the context of a modern power grid.

Key topics

- Classification of on-grid systems according to connection method (domestic, directly connected),
- Structure and components of on-grid solar power plants,
- Principle of operation and integration with the power grid,
- Measurement, calculation and economic aspects of using the on-grid system.

Teaching methods

- Lecture and discussion - Explanation of the principles of operation of on-grid solar power plants and integration with the power grid.
- Group work - Analysis of the key components of the on-grid system.

Evaluation

- Critical Analysis - Discussion of the advantages and challenges of on-grid solar systems versus off-grid systems, in the modern power grid.

4.5.1.3. Hybrid solar photovoltaic systems

Objective of the teaching unit

Acquaint students/participants with the working principle, structure and components of hybrid solar photovoltaic systems. Develop an understanding of the combination of different energy sources and storage to ensure a stable electricity supply.

Key topics

- Classification of hybrid solar systems,
- Integration of solar panels with batteries, generators, wind turbines and hydroelectric power plants,
- Block diagram and structure of hybrid systems,
- Application and flexibility of hybrid systems in energy supply.

Teaching methods

- **Lecture and discussion**- Explanation of the principle of operation and integration of different energy sources in hybrid systems.
- **Case study**- Overview of examples of hybrid systems in practice and analysis of their effectiveness.
- **Group work**- Students/Participants create a simulation of a hybrid system with different energy sources.

Evaluation

- **Research paper/PPT presentation**- Comparative analysis of the advantages and challenges of off-grid, on-grid and hybrid solar power plants.
- **Critical analysis**- Discussion on the possibilities of improving hybrid solar systems in the context of the energy transition.
- **Quiz**- Questions about off-grid, on-grid and hybrid power plants.

Exercise: Research paper - Comparative analysis of off-grid, on-grid and hybrid solar power plants

Exercise goal:

Develop analytical and research skills by comparing different solar energy systems and connect theoretical knowledge with practical applications.

Instructions for performing the exercise

Introduction

- Explain the basic characteristics of off-grid, on-grid and hybrid solar power plants.
- Ask key research questions:
    - What are the advantages and challenges of each system?
    - What factors influence the choice of the appropriate type of power plant?
    - How do different systems contribute to energy sustainability?

Research

- Students/Participants collect data on the principle of operation, advantages and challenges and application in different conditions.

Analysis

- They assess which system is most suitable for specific locations and user needs.
- They identify the key economic and environmental factors that influence the implementation of solar systems.

Presentation of results

- Students/Participants create a PPT presentation or written report with analysis and key conclusions.
- Each group presents the results, followed by a discussion on optimal solutions for the future of solar energy.

Quiz 5: Division of solar photovoltaic systems into off-grid, on-grid and hybrid power plants

https://forms.office.com/e/77hGTtsPQV

1. What characteristic distinguishes off-grid solar photovoltaic systems from on-grid systems?

a) Off-grid systems are connected to the power grid
b) Off-grid systems use batteries for energy storage
c) On-grid systems do not produce electricity
d) On-grid systems work only in night conditions

2. Where are independent (off-grid) solar photovoltaic systems most often used?

a) In urban areas with stable power supply from the network
b) On the roofs of commercial buildings connected to the network
c) In remote areas without access to the power grid
d) At industrial plants in city centers

3. What is the main characteristic of on-grid solar power plants?

a) They are not connected to the public power grid
b) They use only renewable energy sources without batteries
c) Surplus produced energy can be delivered to the network
d) They use only solar collectors instead of photovoltaic panels

4. What are the names of solar power plants that combine multiple sources of energy, such as wind power plants or diesel generators?

a) On-grid power plants
b) Off-grid power plants
c) Hybrid power plants
d) Floating power plants

5. What is the advantage of floating solar power plants?

a) I can work without sunlight
b) They reduce the occupation of land space and increase efficiency by cooling with water
c) They are more efficient than all other solar technologies
d) They do not require inverter systems for energy conversion

6. What are the main criteria for dividing solar photovoltaic systems?

a) Panel color and installation height
b) Work autonomy, location, system size and panel technology
c) Year of manufacture and duration of the system
d) The use of accumulators and the number of employees in the power plant

7. What are the main characteristics of portable (mobile) off-grid solar power plants?

a) Large capacities and high efficiency
b) Fixed installation and great longevity
c) Mobility, simple installation and limited capacity
d) They do not use battery energy storage

8. Which solar photovoltaic power plants belong to the group of large power plants?

a) Those whose power is up to several tens of kilowatts
b) Those whose installed capacity is expressed in megawatts (MW)
c) Small power plants intended for home installations
d) Portable power plants with limited capacity

9. What is the main advantage of hybrid solar photovoltaic systems?

a) Lower installation costs than on-grid systems
b) The possibility of combining solar energy with other sources
c) Work exclusively at night when there is no sunlight
d) They do not require maintenance

10. Which photovoltaic panel technologies are used in modern solar power plants?

a) Monocrystalline, polycrystalline, thin-layer, perovskite and organic cells
b) Exclusively polycrystalline cells due to their longevity
c) Only organic photovoltaic cells because they are environmentally friendly
d) Plate thermal collectors and parabolic reflectors

4.5.2. Elements of solar photovoltaic systems, function and assembly principle

Objective of the teaching unit

Familiarize students/attendees with the key components of solar photovoltaic systems, their functions and assembly procedure. Develop an understanding of proper system installation and integration to ensure system efficiency and longevity.

Key topics

- Supporting structures of photovoltaic panels (types, assembly procedure, components),
- Electrical energy storage systems (battery systems, characteristics, installation procedure),
- Charging regulators (function, assembly procedure and configuration),
- Inverters (function, connection to panels, batteries and network),
- Electrical installations and protection systems (cabling, distribution cabinets, grounding, lightning protection),
- Monitoring and management system (sensors, software, alarms).

Teaching methods

- Lecture and visualization - Presentation and analysis of key components of solar photovoltaic systems.

Evaluation

- Key Terms Quiz - Quiz: Elements of Solar Photovoltaic Systems, Function and Mounting Principle.
- Critical analysis - Discussion of the challenges of mounting photovoltaic systems.

Quiz 6: Elements of solar photovoltaic systems, function and assembly principle

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

1. What is the basic function of the supporting structure of photovoltaic panels?

a) Conversion of solar energy into electrical energy
b) Ensuring the mechanical stability of the panel and optimal positioning
c) Reduction of panel temperature during operation
d) Generation of electricity from the wind

2. What type of supporting structure enables automatic tracking of the Sun during the day?

a) Fixed structures
b) Structures for mounting on the roof
c) Systems with monitoring the position of the Sun
d) Underground supports

3. What materials are most often used to make the supporting structures of solar panels?

a) Plastic and wood
b) Aluminum and steel
c) Copper and rubber
d) Ceramics and concrete

4. What is the basic function of battery systems in solar power plants?

a) Converting alternating current to alternating current
b) Temperature regulation of solar panels
c) Storage of excess electricity for later use
d) Monitoring of electricity consumption

5. What are the names of the electrical devices that control the charging and discharging of batteries in solar systems?

a) Inverters
b) Charge regulators
c) Transformers
d) Voltage controllers

6. What is the task of the inverter in a solar photovoltaic power plant?

a) Increase in panel temperature
b) Converting alternating current (DC) to alternating current (AC)
c) Reduction of resistance in cables
d) Storage of electrical energy

7. What is the primary role of the switchboard in solar power plants?

a) Production of electricity
b) Protection and distribution of electricity in the system
c) Cooling of solar panels
d) Increasing the efficiency of photovoltaic cells

8. What protective measure is used to reduce the risk of lightning strikes in solar power plants?

a) Placing the panel under water

b) Installation of grounding and lightning protection

c) Reducing the number of solar panels

d) Use of glass supports

9. Which element enables remote monitoring and optimization of the operation of the solar photovoltaic system?

a) Inverter

b) Charging controller

c) System of supervision and management

d) Transformer

10. How are photovoltaic panels installed on the roofs of buildings?

a) Using anchors, roof hooks and rails for fixing the panels

b) By directly gluing the panel to the roof surface

c) Placing panels on the ground next to the object

d) Using wooden supports without fastening

4.6. Technical documentation and technical regulation

Objective of the teaching unit

Acquaint students/participants with the types of technical documentation and regulations in the solar photovoltaic industry. Develop an understanding of the standards, design documents and safety regulations governing the operation of solar power plants.

Key topics

- Types of technical documentation (project documentation, manufacturer's documentation, test protocols, certificates),
- Standards and technical regulations in the field of solar photovoltaic systems,
- Interpretation of the projectdocumentation (principle diagrams, block diagrams, single-pole diagrams).

Teaching methods

- **Lecture and discussion**- Explanation of the importance of technical documentation and regulations.
- **Practical demonstration**- Review and analysis of technical documentation of solar power plants.
- **Studycase –**Analysis of project documentation of solar plants and interpretation of electrical diagrams and symbols in the documentation.

Evaluation

- **Critical analysis**- Discussion on the importance of compliance with regulations in the maintenance of solar systems.

4.7. Material, tools, equipment and devices for work on the construction and maintenance of solar photovoltaic systems

Objective of the teaching unit:

To acquaint students/participants with the types of materials used in the construction and maintenance of solar photovoltaic systems, their properties and methods of application.

Key topics:

- Material,
- Tool,
- Equipment and devices,
- Specializedmachines and vehicles.

Teaching methods:

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

Evaluation:

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

Practical exercises:

Task 1: Recognition and analysis materials for work in solar photovoltaic systems

Exercise goal:

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.

Material and tools:

- Samples of different types of materials (copper and aluminum conductors, insulating materials, plastic and metal pipes, protective sheaths),
- Technical documentation and manufacturer's catalogs,
- Measuring tools (micrometer, crimping pliers, insulation stripping knife),
- Protectiveequipment (gloves, safety glasses).

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 the specificworking 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 the students/participants can independently choose the appropriate onematerial for various installations.

Task 2: 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.

Material and tools:

- Basic hand tools (pliers, screwdrivers, scalpels, knives for removing insulation),
- Power tools (drill, sander, soldering iron, hot air gun),
- Testers and measuring instruments (multimeter, voltage tester, ammeter),
- Safety equipment(protective gloves, safety glasses, work clothes).

Instructions for teachers:

- 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 techniquework.

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 installationstasks.

5. CONSTRUCTION OF SOLAR PHOTOVOLTAGE SYSTEMS

5.1. Preparatory works on the construction of solar photovoltaic systems

Objective of the teaching unit

It is suggested that this teaching unit be realized in cooperation with a local company that deals with the installation of solar panels.

Acquaint the students/participants with the key stages of preparatory work before the installation of solar photovoltaic systems. Develop an understanding of technical documentation, proper assessment of location and organization of equipment, and the importance of safety measures.

Key topics

- Interpretation of technical documentation (project drawings, system specifications, safety standards),
- Organization of materials, tools and equipment for assembly,
- Assessment and preparation of the mounting base (roof bearing capacity, soil analysis, structural stability),
- Identification and removal of shading sources,
- Optimal orientation and tilt of solar panels,
- Safety measures and labelingworkspace.

Teaching methods

- **Lecture and visual presentation**- Use of technical diagrams and photos to explain the preparatory work and organization of the installation.
- **Demonstration**- Demonstration of correct assessment of the surface, use of measuring instruments and safety equipment.
- **Discussion and group work**– Analysis of challenges depending on the type of location and environmental factors.
- **Practical exercises**- Students/participants perform a site assessment using measuring equipment, analyzetechnical documentation and prepare assembly equipment and tools.

Evaluation

- Analysis of technical solutions - Students/participants study technical drawings and discuss the correct orientation and tilt of the solar panels.
- Discussion and practical assessment – Evaluation of student/participant understanding through analysis of different field preparation methods.
- Demonstration of safety measures - Students/attendees demonstrate proper use of protective equipment and organizationworkspace.

Practical exercises:

Task 1: Site assessment for a solar power plant

Exercise goal:

Students/Participants will learn how to properly measure the slope and orientation of the roof/ground using measuring instruments to ensure optimal efficiency of the solar PV system.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Ensure a safe environment for performing measurements.
- Prepare the necessary measuring instruments(inclinometer, compass, solar analyzer).

Explanation of the task:

- Explain the importance of orientation and inclination in the optimization of solar production.
- Demonstrate how to usemeasuring instruments for precise measurements.

Running the simulation:

- Participants measure the slope of the roof or ground using an inclinometer.
- They use a compass to determine their orientation to the south.
- They compare the obtained data.with technical guidelines for optimal energy production.

Evaluation and final check:

- Compare the measured values with the recommended parameters for the solar installation.
- Discuss possiblechallenges in measurement and suggestions for improvement.

Task 2: Preparation of assembly equipment and tools

Exercise goal:

Participants will learn how to properly organize the necessary materials and set up safety measures before installing solar panels.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Ensure all materials and tools are available and organized.
- Check securitymeasures at the work location (protective equipment, barriers, signaling).

Explanation of the task:

- Explain the role of each tool and material in the assembly process.
- Demonstrate proper handling of equipment and safe installation of assembly structure.

Running the simulation:

- The participants arrange and organize the materials according to the stages of assembly.
- They check the correctness of assembly equipment and safety systems.
- They set up temporaryprotective measures before starting work.

Evaluation and final check:

- Check that all materials and tools are properly prepared.
- Discuss possibleimprovements in the organization of assembly works.

5.2. Installation of supporting structures and photovoltaic panels

It is suggested that this teaching unit be realized in cooperation with a local company that deals with the installation of solar panels

The aim of this teaching unit is for students/participants to acquire theoretical and practical knowledge about the assembly of load-bearing structures and photovoltaic panels. The focus is on proper installation, safety measures and optimizing the performance of the solar PV system.

Key topics:

- Determining the location and preparing the ground,,
- Creation of the foundation and assembly of the supporting structure
- Installation of photovoltaic panels,
- Correct panel tilt and orientation,,
- Laying and connecting DC cables
- Securityassembly measures.

Teaching methods:

- **Lecture with visual displays**- Presentation of different types of carriers and their technical characteristics.
- **Demonstration**- Demonstration of practical assembly of the supporting structure and panels using appropriate tools.
- **Discussion and group work**– Analysis of the best installation methods depending on the specifics of the location.
- **Workshop work**– Students/participants in groups simulate the assembly of panels using models or real components.

Evaluation:

- **Analysis of technical solutions**- Students/students analyze different types of supports and mounting systems.
- **Discussion and practical assessment**- Exchange of opinions on assembly challenges and methods of ensuring stability.
- **Demonstration**- Practical execution of mounting of supports and panels with evaluation of precision and safetywork.

Videos:

Procedure for roof assembly of supporting structure and solar panels

https://www.youtube.com/watch?v=X51ZnslbWNY

Practical exercises

Task 1: Mounting the photovoltaic panels on the supporting structure, while checking their alignment and stability

Exercise goal

Participants will learn how to properly mount photovoltaic panels on the supporting structure, ensure their stability and alignment, and perform a basic check of the correctness of the installation.

Instructions for performing the exercise:

Preparing the classroom or workspace

- Ensure that all necessary materials and tools are available at the workplace.
- Check the safety of the work surface and install protective equipment.
- Divide students/attendees into smaller groupsgroups and distribute tasks.

Explanation of the task

- The teacher explains the importance of proper assembly of photovoltaic panels and their role in the production of electricity.
- Explain the importance of panel orientation and tilt for optimal system efficiency.
- Explain the procedure for attaching the panels to the supporting structure using appropriate brackets and clamps.

Running a simulation

- The teacher demonstrates the assembly of a single photovoltaic panel, explaining the steps in real time.
- Students/attendees observe the demonstration and ask questions about the assembly process.
- Special attention is paid to the correct use of tools and safety measures.

Independent work of students/participants

- Students/participants in groups assemble the panels on the prepared supporting structure.
- The teacher monitors the work and corrects any mistakes.
- It checks the stability of the structure and the correct fastening of the panels.

Evaluation and final check

- The teacher checks the alignment of the panels and the stability of the joints.
- Using a spirit level or inclinometer, check that the panels are set at the correct angle.
- Students/attendees participate in analyzing potential errors and discussing possible improvements.

Task 2: Connecting the photovoltaic panels, according to the technical documentation with the correct laying of the DC cables

Exercise goal

Students/Participants will learn how to properly connect photovoltaic panels in accordance with the technical documentation, ensure safe laying and routing of DC cables, and perform a basic check of the system's electrical parameters.

Instructions for performing the exercise:

Preparing the classroom or workspace

- Ensure that all necessary materials and tools are available and organized.
- Check that students/attendees are equipped with appropriate protective equipment.
- Divide students/attendees into smaller groups for more efficient work.

Explanation of the task

- The teacher explains the principle of connecting photovoltaic panels and different types of connections (series, parallel, mixed).

- Explain the importance of proper cable sizing and the use of MC4 connectors.
- Explain the rules of safe handling of cables and connectors.

Running a simulation

- The teacher demonstrates connecting the photovoltaic panels, explaining each step.
- Demonstrates proper use of cable splicing tools and joint testing.
- Explains the measurement of electrical parameters using a multimeter.

Independent work of students/participants

- Students/participants in groups connect the panels in accordance with the technical documentation.
- They lay the cables correctly and secure them with UV-resistant ties and protective tubes.
- The teacher monitors the work of the students/students and provides advice on correcting mistakes.

Evaluation and final check

- The teacher checks the safety and correctness of the joints.
- The voltage and current are measured with a multimeter to ensure the accuracy of the connection.
- Students/attendees participate in error analysis and discussion of possible improvements.

5.3. Installation and connection of equipment of solar photovoltaic systems

It is suggested that this teaching unit be realized in cooperation with a local company that deals with the installation of solar panels

Objective of the teaching unit

Students/students should learn the principles of mounting and connecting equipment in solar photovoltaic systems. He will understand the importance of proper placement of supporting structures, organization of cable installations, as well as assembly and connection of inverters and charging regulators. Also, they will learn about the procedures for testing the correctness of the system and the importance of grounding and surge protection.

Key topics

- Types of support structures for electrical equipment (wall, floor supports, rail mounting, equipment cabinets),
- Organization and protection of cable installations (cable racks, channels, pipes, supports, trenches),
- The procedure for mounting and connecting the inverter and charging regulator,
- Proper connection of solar panels, batteries and distribution cabinet,
- Grounding and surge protection systems,
- Functionality testing and system security check.

Teaching methods

Lecture and visual presentation

- Teachers use pictures, diagrams and technical illustrations to explain the assembly and connection of equipment.
- Explanation of the function of the inverter and charge controller using technical diagrams and displays of electrical connections.

Demonstration of procedures

- Practical demonstration of the installation of supports, cabinets and connecting cables.
- Demonstration of proper use of tools and safety precautions during assembly.

Group work and practical application

- Students/participants in groups perform assembly and connection of equipment according to technical documentation.
- The teacher monitors the process, corrects mistakes and explains corrections in real time.

Discussion and analysis of examples

- Analysis of different types of supports and constructions through examples from practice.
- Discussion of mounting challenges in different conditions (roof, floor, floating systems).

Evaluation

Analysis of technical solutions

- Students/participants analyze the technical documentation and suggest appropriate types of supports and mounting methods for specific installation conditions.

Discussion and practical assessment

- Evaluation of student/participant understanding through an exchange of views on the challenges of connecting solar photovoltaic systems.
- Questions and answers on key technical aspects of equipment assembly and testing.

Demonstration and verification of practical work

- Students/attendees demonstrate the installation procedures of inverters and charge controllers.
- Testing the correctness of the connected system using a multimeter and other measuring instruments.
- Checking the security of the installation and grounding of the system.

Videos:

Connecting the elements of a hybrid solar system (step by step)

https://www.youtube.com/watch?v=cCH4IEs1Vzc

Installation and connection procedure of solar photovoltaic panels

https://www.youtube.com/watch?v=oeFeP0JU28w

Practical exercises:

Task 1: Mounting the inverter on the supporting structure and connecting it to the solar panels

Exercise goal:

Participants will learn how to properly mount the inverter on a suitable supporting structure, connect it to the solar panels and check the correctness of the system.

Instructions for performing the exercise:

Student/attendee preparation:

- Acquaint the students/participants with the technical documentation of the inverter.
- Explain the importance of correct positioning of the inverter in the system.
- Emphasize safety precautions during assembly and connection.

Demonstration of the procedure:

- The teacher shows how to choose and mark the appropriate location for mounting the inverter.
- Practically show the procedure of fixing the inverter on the supports.
- Demonstrate connecting DC cables to solar panels and the correct way to measure voltage.

Independent work of students/participants:

- Participants in pairs or smaller groups assemble the inverter according to the technical documentation.
- They connect the inverter to the solar panels, following the rules of polarization.
- They use a multimeter to check the voltage values before making the final connection.

Analysis and evaluation of work:

- The teacher checks the correctness of the connections and the safety of the installation.

- Students/participants analyze mistakes and suggest possible improvements.
- An inverter functionality test is performed and the results are documented.

Task 2: Mounting the charge regulator and connecting it to the battery system

Exercise goal:

The participants will master the procedure of mounting the charging regulator and its connection with the solar panels and battery system, while checking the functionality of the system.

Instructions for performing the exercise:

Student/attendee preparation:

- Present the function and importance of the charge regulator in the solar system.
- Acquaint the participants with the technical requirements of assembly.
- Explain safety precautions when connecting to batteries.

Demonstration of the procedure:

- The teacher demonstrates the mounting of the regulator on the wall bracket.
- It shows the correct procedure for connecting the regulator to the solar panels and battery system.
- Explains the role of fuses and checking voltage values.

Independent work of students/participants:

- Students/students install the charging regulator on the bracket.
- They properly connect the regulator to the solar panels and batteries.
- They perform a voltage measurement to check the connection is correct.

Analysis and evaluation of work:

- The teacher checks the correctness of the installation and connections.
- Potential bugs and improvements are discussed.
- Students/attendees document the measurement results and analyze the performance of the charge controller.

Quiz 7: Installation and connection of solar photovoltaic system equipment

https://forms.office.com/e/g1CTChgFNp

1. What is the main purpose of the supporting structure for electrical equipment in solar photovoltaic power plants?

a) Aesthetic appearance of the system
b) Maintenance of cables in open space
c) Ensuring stability, protection and easy maintenance of equipment
d) Reduction of assembly costs

2. Which type of support is most often used for mounting the inverter inside the technical room?

a) Floor supports
b) Wall brackets
c) Rail mounting
d) Roof racks

3. What is the main reason for using cable shelves and racks in solar systems?

a) Ensuring a stable and safe arrangement of cables
b) Reduction of installation costs
c) Hiding cables from view
d) Reduction of electrical resistance of cables

4. Why is it important to ensure good ventilation when installing the inverter?

a) To better fit the inverter into the space
b) To reduce noise during operation
c) To prevent overheating and extend the service life
d) To increase the speed of electricity transmission

5. Which element in the system controls the process of charging batteries and prevents them from being overcharged or discharged?

a) Inverter
b) Distribution cabinet
c) Charging controller
d) Surge protection

6. What is the basic step when connecting solar panels to an inverter?

a) Connecting the AC cables from the panel directly to the network
b) Proper connection of DC cables according to technical documentation
c) Connecting the charging regulator to the network connection
d) Installation of cables inside the inverter without grounding

7. Which component protects the solar system from surges and atmospheric discharges?

a) Grounding and lightning protection system
b) Charging controller
c) AC distribution cabinet
d) Cable trays

8. Which of the following statements is true about connecting an inverter to a switch cabinet?

a) The inverter is connected exclusively to the AC distribution cabinet
b) The inverter can be connected directly to the grid without protective devices
c) Overload protection should not be taken into account when connecting the inverter
d) The inverter must be connected to the protective and measuring devices in the distribution cabinet

9. What tool is necessary to check the correctness of the joints after connecting the equipment?

a) Hammer
b) Multimeter
c) Vacuum pump
d) Spirit level

10. What is the last step before putting the solar photovoltaic system into operation?

a) Installation of solar panels
b) Cleaning of cables and clamps
c) Testing the system and checking all connections
d) Checking the visual appearance of the system

5.4. Selection of protective equipment and equipment for assembly and disassembly of solar photovoltaic system elements

Objective of the teaching unit

Students/attendees will understand the importance of protective equipment and equipment when working on the assembly and dismantling of solar power plants, including the application of personal and collective protection, protection against electric shock and standard safety procedures.

Key topics

- **Personal protective equipment (PPE)**- Protection of the head, hands, body, legs and respiratory system.
- **Collective protective equipment**– Safety barriers, lightning protection, auxiliary systems for lifting loads.
- **Electrical protection**– Dielectric equipment, insulating pads, tools with insulated handles.
- **Protective equipment check procedure**– Inspection and testing of protective systems.
- **Emergency and evacuation plan**- Response to accidents and rescue procedures in emergency situations.

Teaching methods

Lecture with visual displays

- Use of pictures and diagrams of protective equipment and safety procedures.
- Explanationtypes of protective equipment through practical examples.

Demonstration of elements of protective equipment

- Demonstration of proper use of safety helmet, seat belt and dielectric gloves.
- Demonstrationinsulated tool and voltage tester.

Practical simulation

- Students/trainees install and check protective equipment prior to the simulated assembly task.

Evaluation

- **Test your knowledge through a quiz**– Students/attendees answer questions about protective equipment and safety procedures.
- **Practical check**– Demonstration of proper use of personal protective equipment and safety procedures.
- **Evaluation of research work**- Analysis of collective protective equipment through seminar work and presentation.

Quiz 8: Testing knowledge about protective equipment and protective equipment

https://forms.office.com/e/Esgnr67zKf

1. What is the basic task of a protective helmet when working on a solar photovoltaic power plant?

a) It increases the visibility of workers
b) Enables easier communication
c) Protects against impacts and falling objects
d) Provides additional ventilation

2. What are the basic characteristics of protective footwear for working on solar photovoltaic power plants?

a) Water resistance, light structure, plastic sole
b) Non-slip sole, protective cap, antistatic properties
c) Breathable material, flexible sole, cotton insoles
d) Rubber sole, thermal insulation, sports design

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

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

4. What is collective protective equipment in solar photovoltaic power plants?

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

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

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

Exercise: Seminar paper/PPT presentation - Personal or collective protective equipment in solar photovoltaic power plants

Participants should write a seminar paper/PPT on personal or collective protective equipment used on construction sites of solar photovoltaic systems.

Instructions:

- Explain the importance of safety barriers and safety nets.
- Describe how the lightning protection system on solar panels 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

Debate on the importance of observing protective measures in real working conditions.

- Why is it important to regularly check the correctness of protective equipment?
- What protective measures must be applied when working at height?
- How are collective protective devices installed in a solar photovoltaic power plant?

6. PERFORMANCE OF ELECTRICAL INSTALLATIONS OF SOLAR PHOTOVOLTAGE SYSTEMS

6.1. Elements and method of performing electrical installations of solar photovoltaic systems

Objective of the teaching unit

Students/attendees will understand the basic elements of electrical installations of solar photovoltaic systems, including types of installations, cable systems, electrical installation equipment, grounding and lightning protection. They will acquire practical knowledge about performing installations and safety measures that ensure efficient and safe operation of the system.

Key topics

Types of electrical installations in the solar photovoltaic system

- DC (direct current) installations
- AC (alternating current) installations
- Earthing and surge protection installations
- Installations for monitoring and management

Cable structures and cables in photovoltaic systems

- Cable trays, racks, ducts, pipes, supports and trenches
- DC and AC cables - characteristics and application

Electrical installation equipment

- Circuit breakers, 4p switch with motor drive, disconnectors, fuses
- Surge protection
- Measuring devices and connecting components

Execution of DC and AC electrical installations

- Distribution cabinets, busbars and connection elements

Grounding and lightning protection systems

- Earthing function in a solar power plant
- Elements of lightning protection and their proper installation

Teaching methods

Lecture with visual displays

- Using pictures and technical illustrations to show electrical installations.

Demonstration of electrical installation elements

- Display of different types of protective switches, fuses and surge arresters.
- Demonstration of proper grounding and measuring ground resistance.

Discussion and group work

- Analysis of factors affecting the quality of installations and system security.
- Identification of challenges in performing solar electrical installations and discussion of possible solutions.

Practical simulation

- Students/attendees analyze solar panel and inverter wiring diagrams.
- Practice measuring installation parameters using a multimeter.

Evaluation

Analysis of technical solutions

- Students/attendees analyze the difference between DC and AC installations and their functionality.

Practical assessment

- Checking the correct connection of cables and protective switches.
- Measurement of electrical parameters using correct test methods.

Discussion on the safety of electrical installations

- Evaluation of the student/participant's understanding through the analysis of cases of failures in the electrical installations of solar power plants.

Quiz 9: Elements and method of performing electrical installations of solar photovoltaic systems

https://forms.office.com/e/5CE9DnvbUd

1. What is the basic role of electrical installation in solar photovoltaic power plants?

a) Connecting the panel to the irrigation system
b) Transmission and distribution of electricity from solar panels to consumers
c) Cooling of solar panels
d) Connecting the panel to the rainwater collection system

2. What type of electricity is produced in solar photovoltaic panels?

a) Alternating current (AC)
b) Direct current (DC)
c) Combined current (AC/DC)
d) Induction current

3. What component is used to convert alternating current to alternating current?

a) Charging controller
b) Fuse
c) Inverter
d) Earthing device

4. Where are DC distribution cabinets most often installed?

a) On the panels themselves
b) Inside the low voltage distribution cabinets
c) In the immediate vicinity of solar panels
d) In power poles

5. What is the basic function of the distribution cabinet in the electrical installation of solar photovoltaic systems?

a) Electricity distribution and system protection against overload
b) Reducing the temperature of photovoltaic cells
c) Tracking the movement of the Sun
d) Wind speed optimization

6. Which component provides system protection against overvoltage?

a) Inverter
b) Surge arrester
c) Thermal sensor
d) Photodetector

7. What type of cables are used to connect photovoltaic panels?

a) Standard electrical cables for home installations
b) Specialized DC cables resistant to UV radiation and weather conditions
c) Telephone cables
d) Ethernet network cables

8. What is the main purpose of grounding a solar PV system?

a) Prevention of electromagnetic interference
b) Increase in energy production
c) Protection of the system against overvoltage and electric shocks
d) Panel tilt optimization

9. What is the name of the system for protecting solar installations against lightning strikes?

a) Thermal protection
b) Passive cooling system
c) Lightning rod system
d) Electromagnetic barrier

10. Why is overload protection used in solar power plants?

a) To prevent excessive production of electricity
b) To ensure an even distribution of sunlight
c) To prevent breakdowns due to high currents and voltages
d) To increase the lifetime of solar panels

6.2. Execution of DC electrical installation of solar photovoltaic systems

It is suggested that this teaching unit be realized in cooperation with a local company that deals with the installation of solar panels

Objective of the teaching unit:

Students/participants will acquire theoretical and practical knowledge on the proper execution of DC electrical installation of solar photovoltaic systems, including connecting solar panels, laying cables, system protection and safety measures.

Key topics:

- **Characteristics of DC installation**- Basic specificities of DC electrical installations in solar systems.
- **Laying and protection of DC cables**- Ways and standards of laying cables for the sake of longevity and safety of the system.
- **Connecting solar panels**– Various methods of connecting panels in series and parallel to optimize voltage and current.
- **MPPT (Maximum Power Point Tracking) for optimizing energy production**- Mode of operation, advantages of MPPT technology, scope and connection.
- **Dimensioning of strings and MPPT in solar photovoltaic systems**- Analyzing the panel and inverter datasheet, the voltage in the DC branches of the system and the importance of correctly determining the number of panels in the string.
- **Installation and connection of the DC distribution cabinet**– Key protective and functional wardrobe elements.
- **Connecting the DC installation to the inverter**– AC to AC conversion process and proper connection procedure.
- **Safety aspects of performing DC installations**- Rules for working under high DC voltages and protection against electrical risks.
- **Testing and verifying the correctness of the DC installation**- Measurement of voltage, current and checking the correctness of protective elements.

Teaching methods:

- Lecture and practical instructions - Explanation of key components and their functions and explanation of the practical exercise.
- Demonstration of technical procedures - Practical demonstration of connecting solar panels and laying cables.
- Group System Analysis - Development of examples of different configurations of solar systems and their technical analysis.

Evaluation:

- System Connection Analysis and Discussion - Students/attendees explain the working principles of DC installations and compare different connection methods.
- Practical measurement and connection exercise - Checking the correct handling of cables, connectors and distribution cabinet.
- Questions and answers on safety procedures - Evaluation of understanding of protective measures and rules of operation with direct current.

Practical exercises:

Task 1: Connecting photovoltaic panels in arrays

Exercise goal:

Attendees will learn how to properly connect photovoltaic panels in series and parallel arrays, while checking polarity and measuring voltage to ensure proper system configuration.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Provide a safe environment for the exercise.
- Check for correctnessphotovoltaic panels, cables and tools.

Explanation of the task:

- Demonstrate the difference between series and parallel connections.
- Explain howMC4 connectors and multimeter are used correctly.

Running the simulation:

- Students/students will connect the panels according to the instructions and check the polarity.
- Perform a voltage measurement in order tothe correctness of the joints was confirmed.

Evaluation and final check:

- Check the strength of the connector and the protection of the joints.
- Compare the measured values with the technical onedocumentation.

Task 2: Assembling and connecting the DC distribution cabinet

Exercise goal:

Participants will learn how to properly mount and connect a DC distribution cabinet, with the correct installation of protective fuses and switches according to the technical documentation.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Provide a stable place for mounting the DC distribution cabinet.
- Review all necessarymaterial and tools.

Explanation of the task:

- Explain the purpose of the switch cabinet and its components.
- Demonstrate correcthow to install fuses and DC switches.

Running the simulation:

- Mount the cabinet on a wall bracket or floor structure.
- Connect incoming cablesfrom the solar panels and output to the inverter.

Evaluation and final check:

- Check the correctness of all connections and ensure that the connectors are properly connected.
- ~~Measure the voltage values with a multimeter.~~

Task 3: Connecting the inverter to the DC installation

Exercise goal:

Attendees will learn how to properly connect the inverter to the DC switchboard, check the connections and measure the voltage before putting the system into operation.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Choose a suitable place for mounting the inverter.
- To ensurenecessary tools and equipment.

Explanation of the task:

- Demonstrate the procedure for connecting the inverter to the DC distribution cabinet.
- Explain the importancecorrect polarization when connecting.

Running the simulation:

- Mount the inverter on the support according to the technical specifications.
- Connect the positive and negative cables from the DC distribution cabinet to the corresponding inverter terminals.

Evaluation and final check:

- Check that all connections are made correctly and securely connected.
- Measure the voltage at the input terminals.inverter connections before putting the system into operation.

6.3. Performing AC electrical installation of solar photovoltaic systems

It is suggested that this teaching unit be realized in cooperation with a local company that deals with the installation of solar panels

Objective of the teaching unit

Students/attendees will understand the principle of operation of AC installations in solar photovoltaic systems, learn how alternating electrical installations are performed and how the system is integrated with the electrical distribution network. A special focus will be on the correct laying of cables, installation of protective devices and compliance with safety measures.

Key topics

- The role of AC installation in solar power plants,
- Basic elements of the AC system: inverter, distribution cabinet, fuses, switches,
- Rules for laying and connecting AC cables,
- Connecting the system to the electrical distribution network (PCC),
- Safety measures and standardsperforming AC installations.

Teaching methods

- Lecture and instructions for practical work - Explanation of the operation of AC installations.
- Discussion and group work - Students/attendees analyze different configurations of AC installations and advantages of on-grid and off-grid systems.
- Demonstration and simulation - Presentation of key components of the AC system and simulation of the inverter connection procedure snetwork.

Evaluation

- Practical Assessment – Analysis of AC system schematics and recognition of correct and incorrect installations.
- Questions and Answers on Safety Procedures - Evaluation of understanding of safety measures and rules of operation with DCelectricity.

Practical exercises:

Task 1: Assembly and connection of the AC distribution cabinet

Exercise goal:

Students/students will learn how to properly mount and connect an AC distribution cabinet, including the installation of busbars, protective switches and measuring devices, in accordance with technical documentation and electrical installation standards.

Instructions for performing the exercise:

Preparing the classroom or workspace

- Divide students/participants into groups - each group will have the task of assembling a specific segment of the AC distribution cabinet.
- Review the technical documentation and assembly plan.
- Ensure that the work area is clean and safe for carrying out activities.
- Prepare the necessary tools and protective equipment.

Explanation of the task

- Demonstrate the layout of the AC distribution cabinet and key components.
- Explain the function of busbars, protective switches and measuring devices.
- Emphasizesafety measures when working with AC installations.

Running a simulation

Group 1 – Installation and fixing of the AC distribution cabinet

- Determine the exact position of the cabinet according to the technical plan.
- Attachcabinet to a suitable surface using dowels and screws.

Group 2 – Installation of busbars and protective switches

- Place the busbars inside the cabinet according to the specifications.
- Ensure their proper fixation and check connections.
- Install fusesand circuit breakers and connect them to busbars.

Group 3 – Installation of measuring devices and final check

- Place voltmeters, ammeters and wattmeters in the designated places.
- Connect them with appropriate cables and busbars.
- Visually check all connectionsand make sure they are connected correctly.

Evaluation and final check

- Check the physical stability of the cabinet and all components.
- Measure the voltage and check the correct functioning of the protective switches.
- Discuss possibleerrors and how to avoid them in future installations.

Task 2: Connecting the inverter to the AC system

Exercise goal:

Students/students will learn how to connect the inverter to the AC system, including connecting the AC cables according to the technical documentation and checking the voltage before commissioning.

Instructions for performing the exercise:

Preparing the classroom or workspace

- Divide the students/participants into three groups - each group will work on different segments of connecting the inverter.
- Review technical documentation and explain key connection points.
- Ensure the presence of protective equipmentequipment and tools for safe work.

Explanation of the task

- Demonstrate the layout of the inverter and AC system.
- Explain the working principle of the inverter and the method of converting DC to AC current.
- Emphasize the importancecorrect polarity and protective measures.

Running a simulation

Group 1 - Preparing and checking the inverter and AC system

- Ensure that the inverter is disconnected from the power supply.
- Check the voltage of the AC installationusing a multimeter.

Group 2 - Connecting AC cables

- Find the appropriate connections for phase (L), neutral (N) and earth (PE).
- Connect the AC cables according to the technicaldocumentation and secure them with clamps.

Group 3 – Cable organization and system testing

- Place cables in protective tubes to prevent mechanical damage.
- Measure the voltage at the output of the inverter with a multimeter before switching it on.
- Simulate the operation of the system and check whether the inverter is correctly connected to the grid or local consumers.

Evaluation and final check

- Check all connections and make sure they are firmly connected.
- Measure the voltage and current at the connection points of the inverter.
- Discussabout possible problems when connecting and ways to solve them.

Task 3: Testing the electrical installation of solar photovoltaic systems according to IEC 60364-6

Test the electrical installation of solar photovoltaic (FN) systems according to IEC 60364-6, including checking conductor continuity, polarity, insulation resistance, functional tests and other key parameters to ensure proper system operation.

Material and tools:

- Multifunctional tester for testing electrical installations (e.g. Fluke 1664 FC, Megger MFT),
- Digital multimeter,
- Current clamps,
- Insulation tester (megger),
- Photovoltaic system diagram with test points,
- Protective equipment (gloves, protectiveglasses, voltage tester).

Instructions for performing the exercise:

Continuity testing of grounding and potential equalization conductors

- Check the continuity of the ground conductor using a continuity tester.
- Connect one probe of the tester to the main ground and the other to the protective conductor.
- Read the result and compare.with standard values according to IEC 60364-6.

Polarity test

- Using a digital multimeter, check whether the phase conductor is properly connected.
- Place one probe on the phase conductor and the other on the protective conductor and check the voltage readings.
- If the voltage is notmatches as expected, check and correct the connection.

Combo box test (combiner box string)

- Check the fuses, protective switches and connections in the combiner box.
- Perform a voltage test on the input and output terminals.
- Check the operation ofprotective devices by testing the earthing switch.

Open Circuit Voltage Test (Voc)

- Separate the photovoltaic string from the inverter.
- Using a multimeter, measure the open circuit voltage between the positive and negative terminals of the photovoltaic string.
- Compare measuredvalues with the expected, according to the technical documentation of the panel.

Short circuit test (Isc)

- Connect the ammeter to the circuit of the photovoltaic string.
- Short circuit positiveand the negative terminal and read the short circuit current.
- Compare the measured values with the manufacturer's data.

Functional tests

- Connect the photovoltaic system to the inverter and the grid.
- Check the operation of the inverter at different levels of insolation.
- Test the operation of protective devices by turning off the photovoltaic string.
- Check if the inverter is working properlytracks the MPPT point.

DC circuit insulation resistance test

- Turn off the inverter and photovoltaic strings.
- Connect the insulation tester (megger) to the DC cables and carry out the test at a voltage of 500V or 1000V.
- Check thatwhether the measured values meet the minimum requirements of the standard.

Final check:

- Compare all measured values with the manufacturer's specifications and the IEC 60364-6 standard.
- Identify possible installation errors.
- Document the resultstests in the checklist.

6.4. Execution of grounding installation and lightning protection installation of solar photovoltaic systems

It is suggested that this teaching unit be realized in cooperation with a local company that deals with the installation of solar panels

Objective of the teaching unit

Students/participants will acquire theoretical and practical knowledge about the installation of grounding systems and lightning protection in solar photovoltaic systems. They will understand the importance of these installations for system and user security, as well as the procedures for proper execution, testing and verification.

Key topics:

- The role and importance of grounding in solar photovoltaic systems,
- Elements of the grounding system,
- Procedure for installation and connection of grounding,
- Lightning protection - types and elements,
- Rules and standards for grounding and lightning protection,
- Installation testing and verification.

Teaching methods

- **Lecture with visual displays**- Explanation of basic concepts and the importance of grounding and lightning protection with technical illustrations.
- **Demonstration of elements**- Presentation of different types of grounding devices, conductors and lightning protection components.
- **Practical exercise**– Simulation of grounding, busbar connection and installation testing.
- **Discussion and analysis**- Analysis of examples of incorrect installation and discussion of the most common errors and their consequences.

Evaluation

- Analysis of technical solutions - Students/Participants will analyze different types of grounding and lightning protection.
- Practical assessment - Checking the correctness of the connections and measuring the grounding resistance.
- Discussion and conclusions - Critical analysis of the impact of properly executed grounding on system safety.
- Quiz - A short test with questions about the components and rules of grounding and lightning protection.

Practical exercises:

Task 1: Installation and connection of the grounding system

Exercise goal

Students/Participants will learn how to perform the grounding system of a solar PV system, including placing the grounding rod, connecting the conductors and measuring the grounding resistance.

Instructions for performing the exercise:

Preparing the classroom or workspace

- Provide a suitable field for performing the exercise.
- Prepare ground rods, conductors, measuring instrument and necessary tools.
- Inspect safety equipment and ensure that students/attendees use protective gloves and goggles.

Explanation of the task

- Explain the importance of grounding for the safety of solar power plants.
- Demonstrate the procedure for installing the grounding device and connecting the conductors.
- Explain how earthing resistance is measured and what are the prescribed values.

Running a simulation

- Divide the students/participants into groups and assign them specific tasks:
    - Group 1: Marking locations and digging trenches.
    - Group 2: Placement of earthing devices and connection to busbars.
    - Group 3: Connecting the earthing system to metal parts of the installation.
    - Group 4: Resistance measurement and joint verification.
- Supervise the work of students/participants and ensure compliance with technical specifications.

Evaluation and final check

- Inspect all connections and attached conductors.
- Compare the measured resistance values with the prescribed standards.
- Discuss with students/participants about possible problems and possible improvements in the grounding procedure.
- Document the procedure and register any irregularities.

Task 2: Assembly and connection of lightning protection installation

Exercise goal

Students/Participants will learn how to install and connect the lightning protection elements of a solar PV system, including lightning rods, conductors and grounding rods.

Instructions for performing the exercise:

Preparing the classroom or workspace

- Prepare the field and provide the necessary material and tools.
- Provide protective equipment for work at height if necessary.
- Check the technical documentation for the correct arrangement of lightning rods.

Explanation of the task

- Explain the role of lightning rods and the principle of operation of the lightning protection system.
- Demonstrate the procedure for placing clamps, conductors and grounding.
- Explain security measures and system testing procedures.

Running a simulation

- Divide students/attendees into teams with different tasks:
    - Group 1: Determining and marking the points of installation of lightning rods.
    - Group 2: Installation of lightning rods at the designated locations.
    - Group 3: Connection of conductors with clamps and grounding.
    - Group 4: System Conductivity Testing and Installation Verification.
- Supervise students/attendees and ensure proper implementation of security measures.

Evaluation and final check

- Visually inspect all connection points and mounting elements.
- Verify the electrical conductivity of the system and ensure that all connections meet protection standards.
- Discuss possible installation problems and analyze how to improve the installation of the lightning protection system.
- Document the procedure and record any corrections.

Task 3: Testing of grounding and lightning protection

Exercise goal

Students/attendees will learn how to test grounding and lightning protection systems using proper measurements and checking connections.

Instructions for performing the exercise:

Preparing the classroom or workspace

- Prepare earthing resistance meters and test instruments for lightning protection.
- Provide a safe environment for testing.
- Inspect all connections and ensure all systems are turned off before beginning testing.

Explanation of the task

- Explain methods of measuring ground resistance and verifying conductivity.
- Demonstrate how to properly use a measuring instrument and interpret the results.
- Explain how the results are analyzed and what values must be met.

Running a simulation

- Divide students/attendees into groups with different tasks:
    - Group 1: Measurement of earth resistance using a measuring instrument.
    - Group 2: Checking the integrity of all grounding connections and lightning protection installation.
    - Group 3: Conductivity testing of lightning protection system conductors.
    - Group 4: Analysis of measurement results and comparison with standards.
- Supervise students/participants during the performance of measurements and checks.

Evaluation and final check

- Ensure that all measured parameters meet the prescribed standards.
- Discuss possible mistakes and how to avoid them in future work.
- Document all measurements and possible corrections.
- Prepare a report on the verification of the correctness of the system.

Quiz 10: Grounding and lightning protection of solar photovoltaic systems

https://forms.office.com/e/d8mq2j23jd

1. What is the main purpose of grounding in solar photovoltaic power plants?

a) Increase in voltage in the system
b) Maintaining the temperature of the panel
c) Ensuring safety and preventing electric shock
d) Reduction of installation costs

2. What components are used to make the grounding system?

a) Lightning rods and fuses
b) Metal rods, grounding conductors and busbars
c) Solar panels and batteries
d) DC cables and MC4 connectors

3. Where are grounding devices placed in solar photovoltaic power plants?

a) On top of the solar panels
b) In the electrical cabinet
c) In the ground, in certain locations
d) Inside the inverter

4. What is the function of the lightning protection system in the solar power plant?

a) Reduces energy losses in the system
b) Attracts and safely conducts lightning strikes to earth
c) Increases the efficiency of solar panels
d) Regulates the operation of battery systems

5. What are the basic elements of a lightning rod installation?

a) Lightning rods, discharge conductors and earthing conductors
b) Solar panels, inverter and battery system
c) Switches, fuses and charging regulator
d) Metal supports, protective strips and AC distribution cabinet

6. What tool is used to measure ground resistance?

a) Multimeter
b) Earth resistance meter
c) Thermal imaging camera
d) Ammeter

7. What are the key steps in the lightning protection installation procedure?

a) Installation of solar panels and batteries
b) Installation of lightning rods, connection of conductors and earthing conductors
c) Connecting the DC cables to the distribution cabinet
d) Installation of the inverter and connection to the network

8. What ensures proper grounding of electrical equipment?

a) Connection of all metal parts with earthing conductors
b) Installation of additional solar panels
c) Using only plastic supports
d) Earthing connection only to the lightning rod

9. What is the main function of the ground bus?

a) Distribution of alternating current to the inverter
b) Connecting several grounded conductors into a single system
c) Temperature regulation within the electrical installation
d) Maintaining a constant voltage in the AC installation

10. Why is it important to test grounding and lightning protection after installation?

a) To ensure the safety and functionality of the system
b) To increase the output power of the solar panels
c) To optimize the energy consumption of the inverter
d) To avoid overheating of DC cables

6.5. The most common mistakes when installing a solar photovoltaic system

Objective of the teaching unit

Students/Participants will learn about the most common mistakes that occur during the installation of photovoltaic systems and how to avoid them. He will understand the importance of proper sizing of the system, optimization of the panel position, proper execution of electrical installations and the importance of regular system maintenance.

Key topics

- Incorrect sizing of the system,
- Panel placement errors,
- Faults in electrical installations,
- Errors in assembly and safety measures,
- Lack of monitoring and maintenance,
- How to avoid installation errors?

Teaching methods

- Lecture and presentation - Explanation of key mistakes in the installation of photovoltaic systems with illustrations and case studies.
- Demonstration - Demonstration of correct and incorrect installation of photovoltaic systems and analysis of technical problems on real examples.
- Discussion and analysis - Discussion of the most common challenges in the installation of photovoltaic systems and exchange of experiences.
- Work in groups - Analysis of scenarios from practice and proposing solutions for correcting errors.
- Case Study - Students analyze documented cases of improperly installed systems and make recommendations for improvement.

Evaluation

- Oral examination - Questions about the most common mistakes and installation rules of photovoltaic systems.
- Presentation of solutions - For a specific example, each group prepares a report on potential errors and proposes methods of prevention and optimization of photovoltaic systems.

7. OPERATION AND MAINTENANCE OF SOLAR PHOTOVOLTAGE SYSTEMS

7.1. Preparatory work and initial testing of solar photovoltaic systems

Objective of the teaching unit

Students/participants will learn how to properly conduct preparatory work and initial testing of a solar photovoltaic system before its commissioning. He will understand the importance of technical documentation analysis, intervention planning and system functionality testing.

Key topics

- Review of technical documentation and analysis of key system parameters,
- Preparation of tools, equipment and protective means,
- Planning of activities and schedule of interventions,
- Pre-launch system check and component testing,
- Activation of inverters and solar panels with operation control,
- Verification of communication systems and protective devices.

Teaching methods

- Lecture and presentation – Explanation of technical documentation and key system parameters with visual displays.
- Discussion and group work - Analysis of possible challenges during preparatory work and system testing.
- Practical simulation - Performance of test measurements and analysis of results.

Evaluation

- Theoretical knowledge test - Students/participants answer questions related to technical parameters, testing procedures and safety measures.
- Practical task - Simulation of system testing (voltage measurement, checking connections and protective devices).
- Final report - Students/participants prepare a short technical report with the results of the checks and suggested improvements.

Practical exercise:

Task: Initial testing of the solar photovoltaic system

Exercise goal:

Attendees will learn how to properly perform a visual inspection, electrical measurements and activation of a solar PV system, following technical documentation and safety guidelines.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Ensure that the work area is safe and that all tools and equipment are accessible.
- Check the correctness of protective equipment and measuring instruments.

Explanation of the task:

- Explain the importance of technical documentation and safety procedures when testing a solar photovoltaic system.
- Demonstrate proper use of measuring instruments such as multimeter, ammeter and thermal imaging camera.

Running the simulation:

- Analyze system electrical schematics and verify key component locations.
- Perform a visual inspection of connections, cables, grounding and protective devices.
- Measure the DC voltage between the solar panels and the inverter, as well as the AC output voltage of the inverter.
- Use a ground tester to check the continuity and resistance of the connections.
- Activate the inverter and monitor the initial operating parameters of the system.

Final check:

- Check the correctness of all connections and protection systems.
- Document all measurements and record the results in the technical documentation.
- Ensure that the system functions in accordance with the set parameters before official commissioning.

7.2. Monitoring of system operating parameters

It is suggested that this teaching unit be implemented in cooperation with a local company that deals with the maintenance of solar panels.

Objective of the teaching unit

Students/participants will acquire knowledge and skills needed for continuous monitoring of operating parameters of solar photovoltaic systems, detection of irregularities and optimization of system operation. They will learn how to analyze key performance indicators, use different monitoring methods and implement remote monitoring software systems.

Key topics

- Continuous monitoring of voltage, current and power - The importance of measuring the basic parameters of a solar photovoltaic system and analysis of deviations.
- Measurement of solar irradiation in real time - Irradiationometers, importance and methods of monitoring.
- Monitoring of panel temperature and intensity of solar radiation - Influence of temperature factors and shading on system performance.
- Technologies for optimization and security - a practical example.
- Cost-effectiveness and economic benefits.
- Using remote monitoring software systems - Implementation of SCADA systems, web applications and data collection and analysis process.

Teaching methods

- Lecture and instructions for practical work - Explanation of the importance of working parameters with examples from practice.
- Demonstration - Practical measurement of panel voltage, current and temperature using measuring instruments.
- Discussion and group work - Analysis of possible failures and proposing solutions based on the monitored data.
- Using software tools - Working with software solutions for remote system monitoring and historical data analysis.
- Practical exercise - Using online software to predict the production of photovoltaic systems for a specific example (10kW).

Evaluation

- Theoretical knowledge test - Students/participants answer questions related to key operating parameters and system monitoring methods.
- Practical exercise - checking of practical work.

Practical exercise:

Task: Using online software to predict the production of a 10 kW solar photovoltaic system

Exercise goal

The goal of this exercise is for students to gain practical knowledge about the analysis and optimization of solar energy production using online software tools. Students will simulate the various factors that affect the output of a 10kW solar PV system and understand how geographic location, tilt, orientation and losses affect system performance.

Instructions for performing the exercise:

Preparation of workspace and tools

- Ensure that all students have access to computers or tablets with an internet connection.
- Open online software for predicting production of solar photovoltaic systems (PVGIS, PVsyst, SAM, HOMER Energy).
- Prepare specifications of solar photovoltaic systems:
  - Total power: 10 kW (25 panels with a power of 400 W each).
  - Inverter: Power 10 kW.
  - Panel tilt: 30° (standard optimization).
  - Orientation: South (180°).
  - Loss coefficient: 15% (cables, temperature, dirt).
- Students choose the region in which they want to analyze the production of solar photovoltaic systems.

Data entry into the software

- Students enter the geographic coordinates of the location (city/state).
- They define the basic parameters of solar photovoltaic systems (inclination, orientation, panel and inverter type).
- They adjust the average losses in the system.

Simulation execution and analysis of results

- Run a simulation to obtain data on expected monthly and annual energy production.
- Students analyze how production varies throughout the year and how seasonal changes affect performance.
- Compare energy production in different locations (eg coastal vs continental region).

Running a simulation

System optimization

- Students simulate a change in panel inclination (15°, 45°) and analyze the impact on production.
- They change the orientation (southeast, southwest) and compare the results.
- They analyze how shading and dirt reduce the production of the system.

Final check

- Comparative analysis of results: Students compare the obtained results with theoretical expectations.
- Discussion:
  - Which configuration gives the best production?
  - How does location and climate affect the performance of solar PV systems?
  - How does the software help in realistic planning of solar power plants?
- Drawing conclusions:
  - Identify the optimal parameters for a specific location.
  - Propose the best solutions for improving the performance of the photovoltaic system.

7.3. Preventive maintenance and diagnostics

It is suggested that this teaching unit be implemented in cooperation with a local company that deals with the maintenance of solar panels.

Objective of the teaching unit:

Students/participants will acquire the knowledge and skills needed to preserve the efficiency and prolong the life of the System by applying preventive maintenance procedures. Understand the importance of regular preventive maintenance in order to prevent unplanned breakdowns.

Key topics:

- Visual inspection of solar photovoltaic systems - inspection of panels, construction, cables, connectors and protective devices.
- Cleaning and maintenance of components - cleaning procedures of solar panels, protection of cables and ventilation systems.
- System diagnostics - testing of voltage, current, grounding resistance and protective devices.
- Data monitoring and performance analysis - use of software tools to monitor system performance.
- Measurement of grounding resistance and checking of electrical installations - testing of systems under load and checking of connection points.

Teaching methods:

- Lecture and discussion - Explanation of the importance of preventive maintenance and diagnostics.
- Equipment Demonstration - Demonstration of visual inspection, cleaning and system testing.
- Practical simulation - Students/participants simulate the proper maintenance of cleanliness of solar panels using appropriate equipment, as well as checking the correctness of electrical connections.
- Use of digital tools - Using software to monitor and optimize solar systems.

Evaluation:

- Theoretical knowledge test - Students/participants answer questions related to preventive maintenance procedures
- Hands-on Check – Students/trainees demonstrate proper system inspection and testing procedures.
- Diagnostic discussion - Students/participants argue the possible causes of the problem based on the test data.
- Maintenance report - Students/participants prepare a technical report on the results of preventive maintenance.

Practical exercises:

Task 1: Visual inspection and cleaning of solar panels and system components

Exercise goal:

Students/Participants will learn how to properly perform a visual inspection and cleaning of solar panels, cables, connectors and other system components to ensure longevity and optimal operating efficiency.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Provide a safe environment and necessary protective equipment.
- Prepare all necessary tools and materials for inspection and cleaning.

Explanation of the task:

- Explain the importance of proper inspection and maintenance of solar panels.
- Demonstrate how to use an inspection mirror, multimeter and thermal imaging camera.

Running the simulation:

- Participants perform a visual inspection of the panel for damage and dirt.
- They check cables and connectors for signs of overheating or corrosion.
- They use appropriate methods of cleaning panels and cables.

Evaluation and final check:

- Check that all panels are clean and that there are no residual impurities.
- Compare operating parameters before and after cleaning.
- Document any irregularities and suggest improvement measures.

Task 2: Testing of grounding and protective devices

Exercise goal:

Participants will learn how to properly check the grounding system and test the protective devices of the solar photovoltaic system.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Ensure that all measuring instruments are working and available.
- Inspect and ensure that all ground connections are visible and accessible for measurement.

Explanation of the task:

- Explain the importance of grounding and the proper functioning of protective devices.
- Demonstrate the use of an earth resistance meter and a multimeter.

Running the simulation:

- Participants visually check the condition of grounding and connections.
- They measure the ground resistance and compare it with standard values.
- They test the functionality of protective switches and fuses by simulating a short circuit.

Evaluation and final check:

- Compare the measured values with reference standards.
- Check the correctness of all tested protective devices.
- Document the results and suggest improvements to the grounding system.

Videos:

Procedure for cleaning solar photovoltaic panels

https://www.instagram.com/smarthome.co.me/reel/C4fjybxIrch/https://www.youtube.com/watch?v=Q6_bFdkuhOk

7.4. Interventions and troubleshooting

It is suggested that this teaching unit be implemented in cooperation with a local company that deals with the maintenance of solar panels.

Objective of the teaching unit

Students/participants will acquire practical knowledge on the identification, analysis and repair of faults in solar photovoltaic systems. They will learn methods of diagnosing problems, safety procedures during interventions and the proper procedure for replacing or repairing faulty system components.

Key topics

- Determining the place and type of failure - Diagnostics of problems based on monitoring of operating parameters, visual inspections and electrical measurements.
- Preparation for repair of faults - Identification of required parts, tools and safety equipment for carrying out corrective work.
- Safety measures during interventions - Rules for protection against electric shock, mechanical injuries and fire during system repairs.
- Replacement and repair of defective components - Procedures for disassembly and assembly of new panels, inverters, cables and protective devices.
- Post-intervention testing - Checking the correctness of the replaced components, measuring the operating parameters, testing the system in operation and re-commissioning
- Preparation of protocols on corrective works - Recording of failures, performed repairs and proposed preventive measures.

Teaching methods

- Lecture with technical illustrations - Explanation of typical malfunctions, methods of diagnostics and system repair.
- Demonstration - Presentation of fault testing procedures using a thermal camera, multimeter and electrical parameter analyzer.
- Working in groups - Each group analyzes a specific fault, proposes a solution and presents the repair procedure. Practical work of students/participants - Simulation of replacement of damaged solar panels, cables or protective assemblies with the application of safety measures.
- Analysis of cases from practice - Review of documented failures and discussion of possible causes and solutions.

Evaluation

- Theoretical knowledge test - Test with questions on fault detection methods and repair procedures.
- Practical task - Students/participants simulate the diagnosis and repair of a specific fault using available tools and measuring equipment.
- Analysis and Discussion - Group discussion on common problems in solar systems and the best methods to solve them.
- Preparation of a technical report - Each group documents the corrective work performed, describes the repair procedure and provides recommendations for preventing future failures.

Practical exercises:

Task 1: Diagnostics and repair of faults in solar photovoltaic systems

Exercise goal:

Attendees will learn how to identify and troubleshoot solar PV systems using diagnostic tools and procedures.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Ensure a safe working environment and the necessary protective equipment.
- Prepare diagnostic tools and replacement components.

Explanation of the task:

- Explain the procedures for visual inspection of the system.
- Demonstrate the use of a multimeter, a clamp ammeter and a thermographic camera.

Running the simulation:

- Attendees recognize possible faults on panels, cables and the inverter.
- They perform measurements of electrical parameters and thermographic inspection.
- Repair faults by replacing damaged components and adjusting connections.

Evaluation and final check:

- Compare the measured values before and after the repair.
- Check the correctness of the system after repair.
- Document the intervention and suggest improvements.

Task 2: Replacing a defective photovoltaic panel

Exercise goal:

Attendees will learn how to properly disassemble and replace a faulty solar panel, along with proper reinstallation and testing.

Instructions for performing the exercise:

Preparing the classroom or workspace:

- Ensure that the system is switched off and de-energized.
- Review the technical documentation of the replacement panel.

Explanation of the task:

- Explain proper disassembly of panels and safe separation from array.
- Demonstrate the use of connector and bracket release tools.

Running the simulation:

- Attendees remove the faulty panel and inspect the connections.
- They place the new panel on the support and connect it to the system.
- They conduct voltage tests and check connections.

Evaluation and final check:

- Check the physical stability of the mounted panel.
- Test the operation of the system after replacement.
- Document the procedure and record the test results.

7.5. Seasonal and long-term system preparations

Objective of the teaching unit

Students/attendees will learn how to adapt solar PV systems to seasonal changes, how to conduct annual system audits, and how to plan for long-term maintenance and modernization to ensure long-term system efficiency and reliability.

Key topics

- Preparing the system for seasonal changes,
- Revision and optimization of the system,
- Long-term maintenance strategy.

Teaching methods

- Lecture with explanation of seasonal changes - Explanation of seasonal factors and their influence on the operation of solar systems.
- Working in groups - Analysis of different seasonal scenarios and proposing solutions for system maintenance in order to improve maintenance methods.
- Case Study - Analysis of data from real solar power plants and discussion of possible improvements.

Evaluation

- Quiz - Questions about operation and maintenance of solar photovoltaic systems.
- Data Analysis - Interpretation of system performance data from monitoring software platforms.
- Presentation of solutions of group work - Each group creates a plan for the seasonal preparation of the system and proposes a modernization strategy.

Quiz 11: Operation and Maintenance in Solar Photovoltaic Systems

https://forms.office.com/e/Y4DvWyr6Gg

1. What are the basic operating parameters that need to be monitored for solar photovoltaic systems?

a) Color of solar panels and type of construction
b) Voltage, current, power, energy, panel temperature, intensity of solar radiation
c) Number of installed panels and construction weight
d) Area of solar panels and wind strength

2. What is the first step in the process of starting a solar PV system?

a) Installing new cables
b) Review of technical documentation and check of correctness of the system
c) Dismantling the inverter
d) Cleaning the panel from impurities

3. Which method is used for remote monitoring of the operation of the solar photovoltaic system?

a) Optical inspection
b) Software systems for supervision and management
c) Manual measurement of panel temperature
d) Periodic shutdown of the system for checking

4. Why is preventive maintenance important for the operation of solar photovoltaic systems?

a) Reduces the efficiency of the system
b) It increases the operating costs of the solar photovoltaic system
c) Extends the life of components and prevents unplanned failures
d) Enables more frequent replacement of components

5. Which of the listed activities is included in the preventive maintenance of solar panels?

a) Dismantling of the entire system every six months
b) Visual inspection, cleaning and checking of joints
c) Removing the cables and checking their weight
d) Increase of panel voltage above nominal values

6. What is the main goal of system testing under load?

a) Checking inverter operation and voltage stability at different loads
b) Damage to photovoltaic cells
c) Switching off protective devices
d) Impossibility of monitoring electricity production

7. What device is used to detect hot spots on solar panels?

a) Voltmeter
b) Ammeter
c) Thermographic camera
d) Digital caliper

8. What is the first step in the process of repairing faults in solar power plants?

a) Replacement of all system components
b) Determining the location and type of failure using diagnostic methods
c) Random shutdown of the panel
d) Excavation of new foundations for supports

9. What are the basic safety measures when repairing an inverter?

a) Shutting down the system, checking the voltage and using an isolated tool
b) Placing the inverter in water for cooling
c) Increasing the voltage above the permitted limits
d) Switching off only the DC current, while the AC remains active

10. Why is seasonal preparation of a solar PV system important?

a) It allows the system to automatically change the mode of operation without the need for supervision
b) It adapts the operation of the system to different weather conditions and prevents potential damage
c) Reduces the need to monitor operating parameters
d) Enables an increase in energy production during the winter

Instructions for carrying out the teaching unit

7.6. Financial aspect of photovoltaic power plants

Objective of the teaching unit

Students/Attendees will understand the key financial factors related to solar PV systems, including operating cost analysis, return on investment (ROI), payback period and long-term economic viability of solar PV systems.

Key topics

Operating costs of solar photovoltaic systems

- Maintenance and component replacement costs (inverter, cables, connectors),
- System monitoring and surveillance costs,
- Insurance and system licensing.

Return on investment (ROI) and payback period

- Calculation of initial investment costs (panels, inverter, installation).
- Analysis of annual savings and income from solar photovoltaic systems.
- Calculation of the investment return period.

Financial benefits of solar photovoltaic systems

- Savings on electricity bills.
- Possibilities of selling excess energy (net metering, feed-in tariffs).
- Lifetime cost and revenue analysis of solar photovoltaic systems.

Cash flow and life cycle analysis of solar photovoltaic systems

- Long-term investment planning and economic analysis.
- The impact of subsidies and electricity price changes on the profitability of solar photovoltaic systems.

Teaching methods

- Lecture with graphic displays - Explanation of key economic terms and cost analysis of solar photovoltaic systems.
- Case study - Calculation of the investment return period for specific examples of solar photovoltaic systems of different powers.
- Group Discussion - Students analyze different financing models for solar PV systems and propose optimal investment strategies.
- Practical assignment work - Students use solar PV system profitability calculators to calculate the ROI and payback period for a given system.
- Scenario Simulation - Analysis of how different factors (location, price of electricity, subsidies) affect the profitability of solar PV systems.

Evaluation

- Oral Examination - Questions on financial parameters of solar photovoltaic systems and return on investment.
- Practical task - Calculation of ROI and payback period for a given solar PV system.
- Case Analysis - Students analyze data from real solar PV systems and draw conclusions about their economic viability.
- Presentation - Each group presents its financial plan for the solar photovoltaic system and provides recommendations for cost and revenue optimization.

8. CONCLUSION AND RECOMMENDATIONS

Effective application of solar photovoltaic systems depends on quality education and continuous professional development, both of students/participants and teachers who prepare them for work in this sector. This manual provides teachers with the necessary methodological guidelines, practical recommendations and teaching strategies that enable thorough and dynamic teaching, with a special focus on the installation and maintenance of solar photovoltaic systems.

Covering a wide range of topics - from the basic principles of operation of solar systems, to the installation of electrical components, to safeguards and maintenance procedures - the manual aims to provide a comprehensive understanding of the field. Special attention is paid to occupational safety and environmental protection, which are covered in a separate chapter, emphasizing the importance of occupational safety and environmental responsibility. Cooperation with local organizations and associations in these areas can further strengthen the awareness of participants about the importance of sustainable work practices and responsible management of resources.

One of the key challenges in the field of solar energy is waste management and recycling of obsolete components, which is a topic that is given considerable attention in the manual. By introducing the principles of the circular economy and encouraging responsible management of resources, students/students are prepared to work in an industry that strives for environmental sustainability.

Great emphasis is placed on practical exercises, which are elaborated step by step, with the aim of the participants acquiring specific skills necessary for working in the field. Through these segments, the authors tried to provide a clear and systematic approach to assembly, installation and maintenance of solar photovoltaic systems, thus training a new generation of experts for one of the most sought-after professions on the labor market. In order to ensure optimal conditions for the performance of practical tasks, cooperation with local companies that can provide the necessary resources and infrastructure for training is proposed.

Aware of the challenges that accompany the organization of practical classes in schools and in adult training frameworks, the authors also propose innovative solutions, among which the implementation of VR (Virtual Reality) and AR (Augmented Reality) simulations stands out. These technologies allow students/participants to master key practical skills in a safe and controlled environment, simulating real work conditions without the risks and limitations of physical training. This approach can significantly improve the quality of teaching, enabling participants to acquire the necessary competencies for working in the industry through an interactive experience.

In addition, in order to bring theoretical knowledge as close as possible to practical application, the manual includes open-source video materials, available through the suggested links. These resources allow students to expand their understanding of key concepts in a visual and intuitive way, and provide teachers with an additional tool to enrich their teaching. Also, the manual contains a large number of quizzes in Microsoft Forms format, which teachers can adapt to their own needs and use as a tool for evaluating knowledge.

In order for solar photovoltaic systems to function reliably and in the long term, preventive and corrective maintenance, timely diagnosis of problems and optimization of the system are of key importance. The manual deals with these aspects in detail, offering teachers guidelines for planning and teaching that will enable students to acquire the necessary competencies to work in this sector. The teacher's role is not only in imparting technical knowledge, but also in developing awareness of the importance of safety at work and a responsible attitude towards the environment.

The global demand for qualified professionals in the solar energy sector is constantly growing, opening numerous opportunities for employment and professional development. Modern education, which combines theory, practice and the use of new technologies, is crucial for the preparation of future experts ready to respond to the demands of the labor market.

Recommendations for teachers

1. **Combine theory and practice**- Focus the teaching on concrete examples and enable students/participants to work with real equipment in order to gain practical knowledge.
2. **Encourage research work**- By involving students/participants in seminars, project assignments and analysis of innovations in the field of solar energy, encourage their interest in new technologies and trends.
3. **Use interactive teaching methods**- Discussions, case studies, video materials and simulations can contribute to a better understanding of key concepts and the development of critical thinking.
4. **Emphasize the importance of safety and environmental responsibility**- Integrate the principles of occupational safety and environmental protection into teaching, with the possibility of cooperation with professional organizations.
5. **Use available digital resources**- Open-source video materials and Microsoft Forms quizzes from the manual can serve as tools for evaluating knowledge and adapting the teaching process to the needs of students/participants.
6. **Introduce modern technologies into education**- VR and AR simulations represent an innovative solution that allows students/participants to acquire practical skills in a safe environment through an interactive experience.
7. **Encourage continuous professional development**- Teachers should follow innovations in the field of photovoltaic systems, participate in professional trainings and improve their work methods.

The manual is designed so that it can be used as teaching material in the final grades of high schools, but also as a resource for courses and trainings in the field of solar photovoltaic systems. Its application enables teachers to efficiently plan and implement teaching, improve student/participant competencies and contribute to the development of the profession in accordance with the modern requirements of the labor market and renewable energy sources.

This manual is not only a tool for professional education, but also a resource for improving the teaching process, adapted to modern learning methods and technological progress. Its use can significantly raise the quality of teaching, enabling students/attendees to acquire practical and applicable skills.

The introduction of new teaching methods, including the application of VR and AR technologies, would further enrich the training process, providing students/participants with realistic experiences in simulated conditions and equipping them to work in the rapidly developing solar energy sector.

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, implementing exercises and checking the achievement of results	11	4
Analog measuring instruments (voltmeter, ammeter, ohmmeter, multimeter, wattmeter, etc.)	5	3
Digital measuring instruments (multimeter, voltmeter, ammeter, wattmeter, frequency meter, power quality analyzer, solar multimeter, multifunctional tester, two-way digital meter, network analyzer, etc.)	5	3
Measuring instruments for measuring non-electric quantities (pyranometer, digital thermometer, actinometer, thermal imaging camera, network analyzer, etc.)	5	3
DC voltage source, function generator, transformer, switches, fuses, relays, etc.	5	3
Electrical installation equipment (switches, 4p switch with motor drive, disconnectors, cam switches, contactors, MC4 connectors, 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.)	5	3
A set of tools for electricians (screwdrivers, pliers for removing insulation, pliers, cutting pliers, 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.)	5	3
Different types of inverters	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: conductors and solar cables, cable heads, cable joints, clamps, couplings, splitters, insulating tapes and other insulating material, PV pipes and boxes, lubricants, rust removers, corrosion protection agents (anti-corrosive 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
Mobile PV sets for PV training, with technical documentation	5	3

SET OF EQUIPMENT FOR MONITORING AND DIAGNOSTIC IN SOLAR PHOTOVOLTAIC SYSTEMS	
1. Control and communication devices	*Data Manager*(Management module for solar photovoltaic system production data) Communication cables (optical or copper for connecting sensors and network) Servers (local or cloud platforms for data analysis) Solar power plant management software (operation monitoring, performance analysis) SCADA system (Supervisory Control and Data Acquisition - supervision and management of solar photovoltaic systems)
2. Sensors and measuring devices	Pyranometer (measurement of solar radiation) Pyroheliometer (precise measurement of direct solar radiation) Temperature sensors (panel and ambient temperature monitoring) Voltage and current sensors (measurement of system electrical parameters) Thermal imaging camera (detection of overheating and "hotspot" points on the panels) Anemometer (for monitoring the effect of wind on photovoltaic panels) Humidity and atmospheric pressure sensors (analysis of the impact of climate conditions on performance) Sensors for monitoring tilt and panel orientation
3. Communication and network equipment	*Industrial Ethernet Switch*(industrial network switch for connecting sensors and SCADA systems) 4G/5G or satellite modems (remote access to data from solar photovoltaic systems) Optical or copper communication cables (connecting the monitoring system) Wireless communication modules (Wi-Fi, Zigbee, LoRaWAN for wireless control)
4. Data storage and analysis systems	*Data Logger* (data collection from sensors of solar photovoltaic systems) Local servers (fast data processing, local SCADA system) *Cloud-based* platforms (long-term data storage and advanced analytics)
5. Systems for environmental monitoring	Sensors for monitoring the environmental impact of solar photovoltaic systems Monitoring of emissions and temperature changes in the environment of solar photovoltaic systems
6. Safety and protective equipment	UPS systems (Uninterruptible Power Supply) *Firewall* devices (network protection of solar photovoltaic systems against cyber attacks) VPN systems (secure remote access to system operation data) Antivirus and IDS/IPS systems (data security monitoring)
7. Cameras and security systems	Thermal cameras (for detecting panel failures due to overheating) IP surveillance cameras (for monitoring the operation of solar photovoltaic systems and preventing equipment theft) Drones with cameras and sensors (for inspecting hard-to-reach parts of a solar PV system)

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Organizations and standardization sources

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- IEEE Power & Energy Society - www.ieee-pes.org
- International Electrotechnical Commission (IEC) – www.iec.ch
- International Energy Agency Photovoltaic Power Systems Program (IEA PVPS) – www.iea-pvps.org
- International Renewable Energy Agency (IRENA) – www.irena.org
- National Renewable Energy Laboratory (NREL) – www.nrel.gov
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