

RENEWABLE ENERGY TECHNOLOGIES

MAINTENANCE OF SOLAR PANELS

DigiEnergy 4.0
DIGITALIZATION IN ENERGY 4.0 TECHNOLOGIES
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EXPLANATIONS

AREA	Renewable Energy Technologies
BRANCH/PROFESSION	Solar Energy Systems
THE NAME OF THE MODULE	MAINTENANCE OF SOLAR PANELS
DESCRIPTION OF THE MODULE	This module will cover basic level solar panels maintenance
DURATION	40/32
PRECONDITION	This module has no prerequisites.
COMPETENCY	It completes maintenance of solar panels
PURPOSE OF THE MODULE	<p>General Purpose You will be able to perform the solar panel maintenance operations practically when the environment of the solar energy systems workshop is provided.</p> <p>Purposes</p> <ol style="list-style-type: none"> 1. You will understand the basic concepts of maintenance, its benefits and drawbacks 2. You will recognize the importance of solar panels maintenance 3. You will identify the solar panels maintenance operations 4. You will be able to identify the safety hazards related to solar panels maintenance operations 5. You will be able to apply safety practices during solar panels maintenance operations



<p>EDUCATIONAL ENVIRONMENTS AND EQUIPMENT</p>	<p>Environment: Renewable energy technologies field, renewable energy systems workshop</p> <p>Equipment: Basic electrical knowledge, basic electronics knowledge, basic mechanics knowledge, measurement tools, screwdriver, control pen, key set, cleaning tools, safety equipment</p>
<p>MEASUREMENT AND EVALUATION</p>	<p>You will evaluate yourself with the measurement tools given after each learning activity in the module.</p> <p>At the end of the module, the teacher uses the measurement tool (multiple choice test, true-false test, fill in the blank, matching etc) to evaluate the knowledge and skills you have gained through module applications.</p>



INTRODUCTION

Dear Students,

We are now on the brink of a Green Energy revolution, when more and more renewable energy production plants are created in order to fight the climate change, to reduce the greenhouse gas emissions and pollution and to ensure a sustainable future for our planet. This offers huge opportunities for people and companies and it is very important for you to understand what Green Energy is and to gain knowledge skills and abilities related to its production as well as with related operations, such as the maintenance of energy production facilities.

The maintenance of solar panels is an important activity as it ensures the maximisation of their solar energy production and ensure they last a long time, with great economic and environmental benefits.

With this module, you will learn about maintenance, in general, and about the solar panels maintenance in particular. The maintenance operations typical for solar panels are discussed together with their importance and benefits. In addition, you will learn about the safety practices related to solar panels maintenance operations, including specific risks and safety measures.



LEARNING ACTIVITY –1

PURPOSE

You will know the basic concepts related to the Maintenance of technical assets.

RESEARCH

- Research on internet terms and definitions related to Maintenance in different industries, with a focus on the basic measures: inspection, service, repair and improvement.
- Research on internet terms and definitions related to Maintenance in different industries, with a focus on the various forms of Maintenance
- Prepare a report of your findings.
- Suggestions on discussion with your colleagues:
 - What are the advantages of scheduled maintenance? It is a good idea in the case of solar panels?
 - How could you conduct condition-based maintenance in the case of solar panels? What tools would you use to monitor the panels condition in real time?

1. BASIC CONCEPTS OF MAINTENANCE

1.1 Definition of Maintenance

Maintenance refers to a combination of technical, administrative and management measures which aim to ensure the preservation of an observed unit (such as a solar plant) or to restore its functionality. It includes four basic measures: inspection, service, repair and improvement.

Inspection: measures for assessing the actual condition of the observed unit, including identifying the cause of wear and deriving the necessary steps to ensure its future use. These include checking, measurement, observation, assessment and deriving consequences.

Service: measures to delay the reduction of the existing wear reserve. These include visual inspection, adjustment, supplement, lubrication, preservation, cleaning, and functional testing.

Repair: measures carried out to restore the functioning of a faulty unit. These include unit exchange, restoration of functions and breakdown resolution. It also aims to eliminate damage or signs of wear, in order to avoid hazards or functional failures.



Improvement: measures to increase unit's functional reliability, maintainability and/or safety without changing its required function. These includes elimination of weak points and improvement in machinery and plant design.



Figure 1: The four basic measures of Maintenance

1.2 Types of Maintenance

Maintenance can be classified in two main categories: scheduled maintenance and unscheduled maintenance.

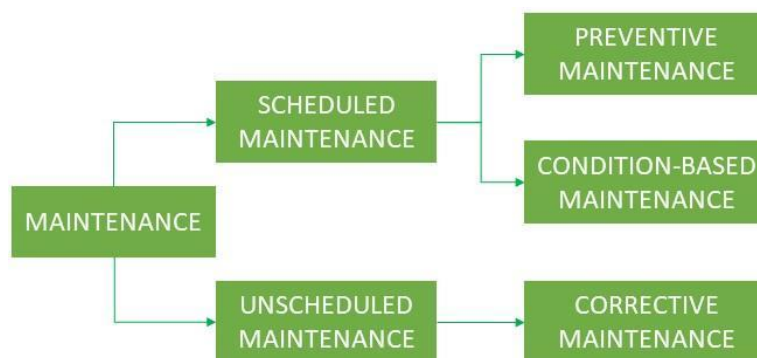


Figure 2: Maintenance categories

1.2.1 Scheduled maintenance

Scheduled maintenance is planned in advance and done at regular intervals. It is based on routine maintenance, repair and prevents faults from occurring. Scheduled maintenance of solar panels should be performed during non-peak hours and preferably during the night hours.

Scheduled maintenance includes two general approaches:

- preventive maintenance
- condition based maintenance

1.2.1.1 Preventive maintenance

Preventive maintenance is performed before machine or system failures occur and involves routine inspection, servicing and cleaning of solar panels at a scheduled interval of time. The goal is to minimize downtime and unnecessary production losses, to improve panels' performance, to increase the availability and to reduce the probability of the equipment failures.

In preventive maintenance, the solar system inspection is conducted according to a routine maintenance strategy. The inspection is normally done during non-peak hours, in order to not affect the power generation. It is recommended to perform cleaning before 11 A.M. and after 5 P.M. and the maintenance during the night hours.

The scheduling and frequency of preventive maintenance depends on a number of factors such as environmental conditions, technology used and warranty terms.

The main activities under preventive maintenance include:

- checking of mounting structure integrity
- module cleaning
- hotspots detection
- junction box servicing
- inverter servicing
- checking the cabling connections
- checking the various supporting and auxiliary components of the solar power plant system



- inverter servicing
- checking the earthing protection
- vegetation control

1.2.1.2 Condition-based maintenance

Condition-based maintenance involves monitoring in real time of equipment condition and plant operations and addresses the potential problems at an early stage to prevent interruptions. This method uses periodic measurements to detect signs of equipment deterioration in order to extend its service life by avoiding imminent problems. It improves the performance and efficiency of solar systems by anticipating failures and avoiding them at an early stage. Condition-based maintenance requires special diagnostic equipment and a good equipment performance monitoring system which can extend and improve the life of the solar plant.

1.2.2. Unscheduled maintenance

Unscheduled maintenance addresses the failures after they have occurred. The important parameters are diagnosis, repair time and speed of response. It includes only one general approach to maintenance management, the corrective maintenance.

1.2.2.1 Corrective maintenance

Corrective maintenance is performed when damage has occurred and involves the repair of faulty equipment. In the short term, this saves staff time and expenses but over the long run, it can prove to be costly in terms of unplanned equipment interruption, repairs, and reduced equipment life.

Corrective maintenance includes:

- Tightening loose connections
- Replacing damaged modules
- Replacing blown fuses
- Repairing blown fuses
- Correcting inverter faults
- Fixing equipment damaged by intruders
- Substituting blown connectors
- Correcting SCADA faults
- Remediating faults of mounting structure



1.3 Benefits and drawbacks of maintenance

In general, good maintenance practices are beneficial for businesses. However, several factors need to be considered in order to understand if maintenance is helping, or hurting, a certain operation.

The main advantages of maintenance are as follows:

- Increases the lifetime of equipment
- Optimises the equipment performance
- Helps avoiding the unscheduled downtimes
- Minimise the costs related to equipment breakdown

There are also some disadvantages related to maintenance:

- Additional expenses
- Lost productivity, when the unit or parts of it need to be shut down during the maintenance
- Possible safety risks



APPLICATION ACTIVITY

Match the terms with their definitions.

Terms	Definitions
a) Maintenance	1) An approach of maintenance involving monitoring in real time of equipment condition and plant operations and addressing the potential problems at an early stage to prevent interruptions.
b) Repair	2) An approach of maintenance performed after machine or system failures occur and involving the repair of faulty equipment
c) Preventive maintenance	3) A combination of technical, administrative and management measures which aim to ensure the preservation of an observed unit (such as a solar plant) or to restore its functionality.
d) Corrective maintenance	4) An approach of maintenance performed before machine or system failures occur and involving routine inspection, servicing and cleaning of solar panels at a scheduled interval of time
e) Condition based maintenance	5) A set of measures carried out to restore the functioning of a faulty unit



MEASUREMENT AND EVALUATION 1

Read the questions carefully and choose the correct answer.

1. What is Maintenance?
 - A. The repair of a broken component
 - B. A combination of technical to ensure the preservation of an observed unit or to restore its functionality.
 - C. A combination of technical, administrative and management measures to ensure the preservation of an observed unit or to restore its functionality.
 - D. A combination of technical and administrative measures to ensure the preservation of an observed unit or to restore its functionality.
2. Maintenance includes the following basic measures:
 - A. Inspection, service and improvement
 - B. Inspection, service, repair and improvement
 - C. Inspection, service and repair
 - D. Inspection, repair and improvement
3. Which of the following are NOT a Maintenance category?
 - A. Inspection
 - B. Scheduled Maintenance
 - C. Unscheduled Maintenance
 - D. Service
4. True or False? Scheduled Maintenance is planned in advance and done at regular intervals:
 - A. True
 - B. False
5. Which of the following sentences about Corrective Maintenance is correct?
 - A. It is performed before machine or system failures occur
 - B. It addresses the failures after they have occurred
 - C. It involves the repair of faulty equipment
 - D. Aims to minimize downtime and unnecessary production losses

EVALUATION



LEARNING ACTIVITY –2

Please compare the answers with the answer key. If you have wrong answers, you need to review the Learning Activity. If you give right answers to all questions, please contact your teacher and pass to the next learning activity.

PURPOSE



Students will learn about the specific Maintenance operations for solar panels.

RESEARCH

- Research examples of solar panels maintenance activities
- Prepare a report of your findings.
- Discuss with some colleagues and make a presentation to your teacher and other colleagues.

2 SOLAR PANELS MAINTENANCE

2.1 The need for maintaining solar panels

The solar panels are designed and built to handle tough weather, snow, and dirt so after installation, unless something breaks, they should function properly without maintenance. From a mechanical point of view, solar panels don't require maintenance as they have no moving parts that need to be serviced, oiled, or cleaned. Solar experts estimate solar panels to last a very long time, around 30 years, virtually without any intervention.

However, a proper maintenance of solar panels guarantees the maximisation of their solar energy production and ensure they last a long time. And it is important that regular maintenance is carried out on solar panel systems to ensure they are operating safely, correctly and efficiently.

Solar panels generally need very little maintenance in order to ensure they keep working properly and producing solar energy. The most common maintenance operation needed is cleaning, to make sure dirt, leaves, and other debris aren't obstructing the solar rays. Usually, this is not a labour-intensive operation, thanks to the solar panels design, which includes very slippery glass that facilitates the removal of unwanted materials during rain.

But dirt and debris can collect on the panels, especially during storms or extended periods without rainfall, and a suitable cleaning is needed to remove this debris and ensure that the solar panels get the optimal amount of sunlight. Also, in countries and areas with abundant snow, more extensive maintenance may be needed when heavy snowfall occurs, as snow deposited on the solar panels can hinder their performance.



A type of maintenance common for solar panels is a periodic inspection of the installation site to make sure everything is working properly.

Other maintenance measures could be taken if problems with the solar panels are noticed or if they aren't producing energy as they should.

The regular maintenance of a solar panel system should check and ensure:

- solar panels are clean, secured in place and free of defects
- there are no deteriorated or corroded parts
- the switches do not have any defects and work properly
- wiring is not damaged or deteriorated
- all electrical components are operating as intended
- fittings and cables are securely attached

Regular maintenance should also include:

- reviewing the inverter display panel for recorded faults
- checking that access to the isolator switches has not been impeded
- making sure the emergency procedures for shutdown and isolation are clearly displayed.

The benefits of regular solar panel maintenance are as following:

- reduces the breakdown
- increases the production of energy
- extends the lifetime of solar panels and plant
- improves the safety

Some negative aspects of solar panel maintenance are related with the costs (for example, cleaning costs can be higher than the economic benefits), safety (especially when the solar panels are installed on roofs) and lost productivity (which can be minimised by avoiding peak hours).

2.2 Inspection of solar panels

The inspection of solar panels includes various measures for assessing their actual condition. These involves checking, measurement, observation, assessment and deriving consequences.

The performance of a solar panels system is vastly affected due to dust accumulation, module shading and solar panels physical integrity issues. Consequently, the inspection should focus on assessing the cleanliness of the panels, check if vegetation management is needed in order to avoid panels shading, and identification of issues related to the physical integrity of panels.



Visual inspection is needed in order to identify the physical integrity of solar modules. The main problems that may be visually identified with minimum tools are:

- moisture condensation within the solar modules
- corrosion of contacts
- delamination of cells
- small cracks that may occur on the cells

2.3 Service of solar panels

Solar panels servicing includes various activities aiming to ensure their optimal functioning for a long time. These mainly comprise visual inspection, cleaning, functional testing and some routine check-ups such as corrosion inspection, vegetation management (shade control), wiring verification, etc.

The general visual inspection activities that must be conducted during visual inspection of a solar plant are as following:

- Equipment grounding verification
- Identification of hazards
- Inspection of weatherproofing systems
- Inspection for wiring damage
- Identification of damage due to corrosion
- Identification of mismatched equipment
- Documentation of findings

The critical activities that must be conducted during visual inspection of solar panels are as following:

- Inspection of solar panels mounting
- Inspection of solar panels integrity (checking for moisture condensation within the solar panels, corrosion of contacts, delamination of cells, cracks on the cells)
- Identification of cell discoloration
- Identification of damage to panel glazing
- Verification of panels shading
- Verification of panels cleanness
- Inspection of unsupported wiring
- Identification of ice damage
- Identification of water ponding



2.3.1 Solar panels cleaning

Since the energy produced by a solar panel depends on the sunlight it is able to collect, anything that blocks its exposure to sunlight affects its performance. An accumulation of dust, debris, and other things will reduce the amount of light that reaches the solar cells, negatively affect the solar panels performance, so their cleaning is required in order to optimise the solar energy production.

A study conducted on Google's campus demonstrated that cleaning solar panels is the best way to maximize the energy they produce. The study involved solar panels installed both flat and tilted. By cleaning the flat panels after they had been in operation for 15 months, their energy output doubled overnight. When they were cleaned again after eight months, their output instantly increased by 36 percent. In the case of tilted solar panels, the rain cleaned them well enough so the reduction in energy output was fairly small.

In desert areas the conversion efficiency loss can be up to 40% over time, according to solar module monitoring results from the Thar Desert, India.

The need and the frequency of solar panels cleaning depends on several factor, in addition to their installation angle. For example, the location of solar panels in a dusty area or near traffic and other factors contributing to dust accumulation on the solar panels may require more often and more effective cleaning.

In countries and areas where is raining often enough, if the solar panels are tilted, the cleaning is very much helped by the rainfall will actually clear away debris that's accumulated on them. However, during the dry season or extended periods without rain, it's important to clean them, to make sure dirt, leaves, and other debris aren't obstructing the solar rays.

In countries and areas where snow is abundant, the removal of the snow deposited on the solar panels may be needed.





Figure 3: "[Solar Panel Cleaning Peachtree Corners G](#)" (CC BY-SA 2.0) by [ppressurewash](#)



Figure 4: "[Snolar Panels](#)" (CC BY-NC-ND 2.0) by [soundslogical](#)

Depending on the size, installation height, available utilities and equipment, etc. the cleaning of solar panels can be done using pressured water, soap and various tools or special machines.





Figure 5: "[cleaning the solar panels](#)" (CC BY 2.0) by [bkusler](#)



Figure 6: Snow removal with a broom. "[Ramping up production at Balcombe's new](#)" (CC BY 2.0) by [1010 Climate Action](#)





Figure 7: "Clears ice and snow from solar panels th" (CC BY-NC-ND 2.0) by U.S. Indo-Pacific Command



Figure 8: Solar cleaning system. Image source: www.sunbrushmobil.com





Figure 9: "Solar panels being cleaned" (CC BY-NC-ND 2.0) by World Bank Photo Collection



Figure 10: "Improving Efficiency of Solar Panels @ G" (CC BY 2.0) by Avinash Kaushik

2.3.1.1 Recommendations regarding solar panel cleaning

- Abrasive sponge or soap should be never used for solar panel cleaning, to avoid scratching the glass. The best way to clean solar panels by using a soft materials and biodegradable soap.



- The best is to clean solar panels when they are moist or wet so any dirt or residue that is stuck on them can be wiped off easily.
- The best is to clean solar panels in the morning or evening. During the middle part of the day the panels can get very hot making cleaning dangerous for both worker and the panels.
- It is important not to use harsh materials when cleaning solar panels as they could cause damage.
- If water is used to clear the snow away, it must be lukewarm. Hot water should be never used for clearing snow off the panels. Solar panels are made of tempered glass, and the extreme temperature difference between hot water and cold panels can crack them.
- Never use a pressure washer on solar panels. Although the glass is quite durable, they are not designed to be hit with high-pressure water jets.
- All necessary work safety measures must be taken

2.3.2 Shade control

Solar systems generate electricity based on the amount of sunlight they receive, therefore when a shadow is cast on panels, the power output decreases substantially. Even a small shade can have a significant impact on the output. According to some experts, up to 40% of the potential solar generation can be lost due to shade. Such a disproportionate power loss is because, many times, solar panels are connected in a series of parallel “strings” so if one panel is covered by shade, then all the connected panels within the string will also loss power. Just 10% shading of a solar array can lead to a 50% reduction in efficiency and even, sometimes, total system shutdown.

Shading can come from a variety of sources:

- Nearby obstructions, such as trees, buildings, chimneys, antennas or poles
- Self-shading from the adjacent solar panel rows
- Horizon shading from the terrain surrounding the installation site
- Other factors such as panel orientation or soiling

For an existing solar plant, it is necessary to perform regular shading analysis of the panels array. These should determine if shading increased over time due to any new objects, such as vegetation growth or man-made obstructions. The historical shading analyses should be kept.

The main activities related to shade control are dealing with vegetation trimming and, when possible, the removal of other obstructions.



2.3.3 Maintenance plans

Maintenance plans are important to ensure necessary tasks are performed. They should include all the necessary maintenance tasks and their respective schedules. The maintenance plans can vary by system configuration, installation type, and location, and may evolve as needed for a particular system. The implementation of a maintenance plan should be recorded in a maintenance log.

One example of a simple maintenance plan is given in the below table.

2.4 Repairing of solar panels

During their lifetime, solar panels are exposed to a variety of situation that can damage them. Even if the panels are very resilient, sometimes accidents and extreme weather conditions can lead to damage that requires solar panel repair.

If a solar panel glass breaks, the foreign elements such as water and dust can travel underneath the glass and impact the energy both absorbed and produced. When a solar panel breaks or cracks, it can still produce high voltage. But it can suddenly stop working because of the exposure to harmful elements. In the event of any damage, the solar panel should be fixed as soon as the broken pieces are noticed.

Solar panel repair involves the full range of fixes, upgrades, and replacements required to bring a broken or underperforming installation back online. Sometimes, only a single solar panel that needs intervention while, other times, other system components may need repair or replacement.



Damaged solar panels can be repaired but many times it is better to replace them with new ones.

2.5 Monitoring the solar panels

A solar panel monitoring system allows for tracking how much energy the panels produce on any given day, and how much they produce over time. Thus, it is possible to see exactly how various external factors affect the panels' performance and how well they are maintaining their efficiency across their lifetime.

The constantly monitoring the energy output of solar panels is very useful in order to recognise the need for cleaning, repairing or replacing solar panels. If a decrease in production is noticed, this could be a sign that the panels are obstructed by something. It might be caused by the dirt and debris collected on the panels so they need to be cleaned. The monitoring system can also alert if a panel breaks or malfunctions and needs repair or replacing.

Monitoring the performance of a solar system through daily, monthly, and annual checks is the best way to detect a problem in the system. Daily checks should involve monitoring the inverter display to ensure that it is working correctly and that the green light is on. Monthly maintenance checks involve checking the cleanliness of the panels, and accumulation of any dust and debris under and around the solar panels array. Annual maintenance checks should involve a thorough check-up of the entire system to ascertain that it is working correctly and the checking of solar panels to ensure that they are clean, free of fractures, scratches, corrosion, moisture penetration and browning.



APPLICATION ACTIVITY

Vote for the best report about terms and definitions related to Maintenance.

Table for reports evaluation

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Total
Report 1					
Report 2					
Report 3					
Report 4					



MEASUREMENT AND EVALUATION 2

Read the questions carefully and choose the correct answer.

1. The regular maintenance of a solar panel system should check and ensure:
 - A. Solar panels are clean, secured in place and free of defects
 - B. There are no deteriorated parts
 - C. There are no corroded parts
 - D. Fittings and cables are securely attached
2. Which of the following are benefits of solar panels maintenance?
 - A. Safety improvement
 - B. Energy production increase
 - C. Guaranteed solar panels repair
 - D. Extended solar panels lifetime
3. Which of the following are negative aspects of solar panels maintenance?
 - A. Safety risks
 - B. Reduces the breakdown
 - C. Energy production loss
 - D. Extended solar panels lifetime
4. True or False? The inspection of solar panels includes checking, measurement, observation, assessment and deriving consequences.
 - A. True
 - B. False
5. Which of the following are NOT activities that must be conducted during visual inspection of solar panels?
 - A. Identification of damage due to corrosion
 - B. Verification of panels cleanness
 - C. Vegetation trimming
 - D. Verification of panels shading
6. True or False? Shadow has a very little impact on the solar panel's energy output, so there is no need perform regular shading analysis or any shade control activity.
 - A. True



B. False

EVALUATION

Please compare the answers with the answer key. If you have wrong answers, you need to review the Learning Activity. If you give right answers to all questions, please contact your teacher and pass to the next learning activity.



LEARNING ACTIVITY-3

PURPOSE

You will learn about the safety rules that need to be applied while performing maintenance operations for solar panels.

RESEARCH

- Research examples of solar panels maintenance activities and make a list with the risks related to these activities
- Prepare a list with measures that can reduce the identified risks
- Discuss with some colleagues and make a presentation to your teacher and other colleagues.

3 SAFE PRACTICES FOR SOLAR PANELS MAINTENANCE

3.1 The risks related to solar panels maintenance

The maintenance of solar panels and systems can be high-risk work if the hazards are not recognized, assessed, and controlled or eliminated. Due to the rapid growth of the solar energy industry, more workers are being exposed to those hazards all the time. They must be properly familiar with its characteristics and the applicable safety measures, which must be followed while maintaining the solar panels.

One reason why solar panel systems are dangerous to work with or near is that they are very often installed on rooftops or on the sides of buildings. Consequently, some maintenance activities may imply working at heights, so falls are a major concern. In addition, the solar panels generate electricity all the time except in complete darkness, so anyone working in proximity to a solar panel must respect, understand, and take precautions when completing their tasks. Some common hazards faced by maintenance workers are:

- Electrocutation or other electric hazards
- Falls from heights
- Slips, trips, and falls
- Weather-related hazards



- Repetitive stress injuries
- Cuts or sprains

Even if it is possible that a solar panels system is maintained by a single worker, this is a dangerous practice because in the event of an incident, there could be no one there to apply the emergency response plans.

3.2 Safe work practices

The risk of accidents related to solar panels maintenance can be reduced through proper training and education of workers, appropriate personal protective equipment and a job safety analysis. A job safety analysis should take into consideration the tasks that can result in injuries for workers who conduct solar panel maintenance work, such as:

- Using power tools
- Working with ladders
- Working in extreme weather
- Climbing or working near roof edges and skylights
- Working alone
- Hoisting and rigging
- Manual handling of heavy material
- Proximity of electrical utilities with chance of electrical contact.

Because of the risks that businesses and workers face, it is necessary for employers to have safety training and protection for their employees. Employers have a duty to take every precaution reasonable to protect their workers and should establish safe procedures for working around photovoltaic systems. This procedure must include an emergency response plan. In addition, companies should update their health and safety policy and program to include procedures for operating around solar installations. The program should call for additional training for workers who may be exposed to solar panel systems. Also, the supervisors must be aware of the program and implement it.

Employers must provide supervision for their workers, appointing a competent person.

As each worksite is unique and presents different risks, it's essential for the solar panels maintenance provider to visit the site, identify safety risks and develop specific plans to address them. This can include:

- Equipment to use for safe lifting and handling of materials
- Type and size of ladders and scaffolding
- Fall protection for rooftop work
- Personal protective equipment for workers



3.3 Safety measures for solar panels maintenance

Before starting any maintenance activities, the solar panels maintenance provider should have a plan in place to protect workers and the public as well as the integrity of the equipment. Detailed, step-by-step maintenance procedures for workers should be prepared based on accurate information about the specific site where maintenance work will take place. This information could be:

- The layout of the site
- How to safely access the site
- Possible hazards that are specific to the site
- The electrical diagram of the solar generation system
- Details on the specific equipment, including operating manuals.

Some of the measures to reduce risks during solar panels maintenance activities are presented below.

3.3.1 Identification of all potential slip, trip, and fall hazards before start working

Trips and falls are among the most common nonfatal injury in the construction industry. The risks can be reduced by following some rules. The work areas should be dry and free from ice, oil and water, and other substances that could cause slips. Any obstruction, such as abandoned tools and electrical cords, should be avoided. The extension cord hazards can be eliminated by using battery operated tools.

If cleaning work takes place at height (for example, on a roof) the workers must take proper care as once the cleaning starts, the roof becomes slippery and they could slide off when they get down. Safety ropes or a harness for support should be used.

If employees are working at height of 1.8 meter or more from the ground level or floor, guardrails should be installed around ledges, sunroofs and skylights. It may be a good idea to also use safety nets. The workers should use a body harness anchored to the rooftop to stop a potential fall. The holes on rooftops, including skylights, as well as ground-level work surfaces should be covered.



3.3.2 Elimination of electrical risks

A solar panels system includes several components that conduct electricity. When these parts are live with electricity generated by the sun, they can cause serious injuries due to electric shock or arc-flash. Even in low-light conditions, systems can create enough voltage to cause injuries. The maintenance workers must be aware that electricity comes from two sources: the solar panels absorbing the sun's light and the utility company. Even if the building's main breaker is shut off, the solar panels system still continues to produce power.

Some measures to eliminate electrical risks are as follows:

- Keep a safe distance from power lines
- Cover the solar panels with an opaque material to block the sun's light
- Treat the wiring coming from a solar panels system as all wires are carrying electrical current
- Use a suitable device to ensure circuits are de-energized before working on them
- Lock out power on systems that can be locked out and tag all circuits where the staff is working on at points where that equipment or circuit can be energized.
- Never disconnect solar module connectors or other associated wiring when it's under load.
- Wear suitable protective equipment

3.3.3 Maximization of ladder safety

Solar panels maintenance often involve working on roofs from ladders and having the right type of ladder and using it correctly is critical to worker safety. The ladders must be inspected before beginning work to make sure they are safe to use. When working near power sources, non-conductive fiberglass ladders should be used.

The ladders must be placed on dry, level ground, away from doorways and walkways. They must be secured to the ground or rooftop for added stability.

Proper lifting and carrying procedures for ladders as well as proper ladder use policies should be developed.

3.3.4 Development of a personal protective equipment policy

Personal protective equipment (PPE) is very important during solar panel maintenance so the employers have to make sure they provide workers with the necessary PPE for their safety. This can include:



- Head protection (hard hats, helmets)
- Protection of extremities (steel-toed shoes with rubber soles, other protective footwear, safety gloves, latex gloves, kneepads)
- Eye and face protection (safety goggles, glasses, face shield, visor)
- Respiratory devices (respirator, dust mask)
- Hearing protection (ear plugs, canal caps, ear muffs)
- Protective clothing
- Harnesses

It is also important that the workers know how to use the PPE and how to maintain it so it is kept in safe and reliable condition. They should know the process to request replacement PPE if it's necessary.

3.3.5 Development of procedures for using power tools and extension cords

Power tools must be kept in safe working condition. The company should assign responsible persons to supervise the proper use and maintenance of the tools. Equipment and electrical cords, must be inspected prior to use to make sure it is safe. Employees must be suitable trained on how to operate all power tools and how to safely perform their maintenance.

3.3.6 Development of hydration policies and safe practices for working in the sun

The employees conducting maintenance activities in hot weather conditions should have drinkable water available on-site. They should be encouraged to ensure regular hydration, in order to avoid dehydration or excessive loss of water from the body. Fluid loss can be life-threatening.

The heat exhaustion risk hazards can be reduced by working during cooler hours of the day.

3.3.7 Consultation with other on-site contractors

Before starting the work on site, the solar panels maintenance provider should be aware of any work that other contractors are performing on-site and communicate with them to identify any potential safety hazards created by their work.



3.3.8 Worker safety training

The workers conducting maintenance activities should be trained in the safe operation of machinery, tools, and equipment, as well as in how to work in accordance with safety policies.



APPLICATION ACTIVITY

Match the risks with the measures to reduce them

Risk	Measures to reduce the risk
a) Dehydration	<p>1)</p> <ul style="list-style-type: none"> ● Use safety ropes or harness. ● Install guardrails around ledges, sunroofs and skylights. ● Use safety nets.
b) Slips and trips	<p>2)</p> <p>Keep a safe distance from power lines Cover the solar panels with an opaque material to block the sun's light Treat the wiring coming from a solar panels system as all wires are carrying electrical current Use a suitable device to ensure circuits are de-energized before working on them Lock out power on systems that can be locked out Wear suitable protective equipment</p>
c) Electrocution	<p>3)</p> <p>Provide drinkable water on the working site Perform mainenance work during cooler hours of the day</p>
d) Falls from heights	<p>4)</p> <ul style="list-style-type: none"> ● Keep the work areas dry and free from ice, oil and water ● Remove any obstruction, such as abandoned tools and electrical cords.



MEASUREMENT AND EVALUATION 3

Read the questions carefully and choose the correct answer.

- Which of the following are common hazards faced by solar panels maintenance workers?
 - Carpal tunnel syndrome
 - Falls from heights
 - Electrocution
 - Slips and trips
- Which of the following factor should be taken into consideration by a solar panel's maintenance job safety analysis?
 - Working with sensitive data
 - Working in extreme weather
 - Working with hazardous materials
 - Working with ladders
- True or False? Employers have a duty to take every precaution reasonable to protect their workers.
 - True
 - False
- Which of the following are NOT measures to reduce risks during solar panels maintenance activities?
 - Identification of all potential slip, trip, and fall hazards before start working
 - Development of a personal protective equipment policy
 - Vegetation trimming
 - Consultation with other on-site contractors
- Which of the following sentences about safety measures for solar panels maintenance are correct?
 - The solar panels maintenance provider should have a plan in place to protect workers, before starting any maintenance activities
 - The solar panels maintenance provider should have a plan in place to protect public, before starting any maintenance activities
 - The solar panels maintenance provider should have a plan in place to protect workers, after completing any maintenance activities
 - The solar panels maintenance provider should have a plan in place to protect the integrity of the equipment, after completing any maintenance activities



6. True or False? Trips and falls are among the most uncommon nonfatal injury in the construction industry.

- A. True
- B. False

EVALUATION

Please compare the answers with the answer key. If you have wrong answers, you need to review the Learning Activity. If you give right answers to all questions, please contact your teacher and pass to the next learning activity.



MODULE EVALUATION

Read the questions carefully and choose the correct answer.

- Which of the following are advantages of Maintenance?
 - Optimises the equipment performance
 - Increases the lifetime of equipment
 - Helps avoiding the unscheduled interruptions
 - Minimise the costs related to equipment failure
- Which of the following are disadvantages of Maintenance?
 - Lost productivity
 - Reduces the lifetime of equipment
 - Additional expenses
 - Maximise the costs related to equipment failure
- Which of the following sentences about solar panels cleaning is correct?
 - Cleaning is the best way to maximize the energy solar panels produce
 - Solar panels cleaning is never necessary for tilted solar panels as the rain will clean them well enough
 - Snow removal is never necessary as the snow will be eventually melted by the sun
 - The best time to clean solar panels is in the morning or evening
- True or False? Damaged solar panels can be repaired but many times it is better to replace them with new ones.
 - True
 - False
- Which of the following sentences about solar panels monitoring is correct?
 - Monitoring the performance of a solar system cannot be used to detect a problem in the system
 - Solar panels monitoring is not useful for tilted solar panels
 - Solar panel monitoring systems can be used to recognise the need for cleaning, repairing or replacing solar panels
 - The best time to monitor solar panels is in the morning or evening
- Which of the following are measures to eliminate electrical risks during solar panels maintenance activities?
 - Covering solar panels with an opaque material
 - Covering solar panels with a transparent material
 - Keeping a safe distance from power lines



- D. Using good quality aluminium ladders
7. Which of the following are personal protective equipment relevant for solar panels maintenance activities?
- A. Helmets
 - B. Safety goggles
 - C. Steel-toed shoes
 - D. Safety gloves
8. Which of the following are measures to maximize ladder safety during solar panels maintenance activities?
- A. Place ladder on wet ground
 - B. Place close to doorways
 - C. Use good quality aluminium ladders when working near power sources
 - D. Secured ladder to the ground or rooftop



ANSWER KEYS

ANSWER KEY TO LEARNING ACTIVITY-1

APPLICATION

a	b	c	d	e
3	5	4	2	1

QUESTIONNAIRE

1	C
2	B
3	A, C
4	A
5	B, C

ANSWER KEY TO LEARNING ACTIVITY-2

1	A, B, C, D
2	A, B, D
3	A, C
4	A
5	C
6	B

ANSWER KEY TO LEARNING ACTIVITY-3

APPLICATION

a	b	c	d
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3	4	2	1
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QUESTIONNAIRE

1	B, C, D
2	B, D
3	A
4	C
5	A, B
6	B

ANSWER KEY TO MODULE EVALUATION

1	A, B, C, D
2	A, C
3	A, D
4	A
5	C
6	A, C
7	A, B, C, D
8	D



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