**Solar Electric Technician Training**

**Module 7: Maintenance and troubleshooting**

# Introduction

Once installation, testing and commissioning of the photovoltaic system is complete, it is important that the system is adequately and periodically maintained to minimise the possibility of failure. In the event of a failure, the in- staller must be able to diagnose the problem, provide and implement a solution. This module describes the maintenance activities for a photovoltaic system as well as solutions for common faults that the installer may encounter while at work.

A well-maintained solar photovoltaic (PV) system ensures optimal performance, longevity, and safety. This handout provides a guide to performing routine maintenance and troubleshooting for solar PV systems, covering essential components such as PV modules, inverters, battery banks, and other protective devices. This is applicable to both single-phase and three-phase solar photovoltaics systems.

## 1.1 Importance of maintenance

Importance of maintenance of a solar photovoltaic (PV) system is crucial for several key reasons:

* **Ensures optimal performance:** Regular maintenance ensures that all system components of the system are operated efficiently, maximizing energy production and meeting expected output levels.
* **Extends equipment lifespan:** Regular maintenance helps detect and correct small issues before they escalate, thus prolonging the lifespan of the equipment.
* **Prevents system failures:** Maintenance helps in identifying potential faults or failures early on. Routine checks help avoid unexpected breakdowns, which could result in prolonged downtime and energy losses.
* **Ensures safety:** Proper maintenance keeps the system safe by ensuring that all safety devices, such as fuses, breakers, earthing systems, and lightning arrestors, are functioning correctly.
* **Maintains system efficiency:** Dirt, dust, or debris on solar panels can significantly reduce their energy output. Cleaning and inspecting the panels regularly maintains their efficiency, ensuring that they are converting as much sunlight as possible into usable electricity.
* **Avoids expensive repairs:** Addressing minor issues during routine maintenance is much less costly than repairing a major failure.
* **Maximizes economic returns:** The efficiency and longevity gained from proper maintenance translate into lower operational costs and higher returns on investment.
* **Environmental responsibility:** Solar PV systems are an essential part of reducing carbon emissions and promoting renewable energy use. A poorly maintained system may not perform to its full potential, which defeats the environmental goal of solar energy.

# Maintenance

There is a common misconception that PV systems do not require any sort of maintenance. This notion is false. As with any other electrical system installation, a PV system should be maintained periodically to ensure safe and reliable functioning.

Maintenance, when done correctly, helps you identify avoidable problems that could lead to system failure. If you notice a fault during routine maintenance, you will proceed with troubleshooting or, in other words, systematic corrective actions.

Maintenance for PV systems can be classified into mechanical maintenance and electrical maintenance. These maintenance categories include the following tasks:

* Visual inspection of components and wiring systems.
* Evaluation of structural attachments and weather sealing
* Cleaning and removal of debris around arrays
* Battery maintenance
* Measuring electrical characteristics and verifying system performance
* Replacement of failed or faulty system components

## 2.1 Categories of PV system maintenance

### 2.1.1 Mechanical maintenance

This refers to maintenance activities involving the support structures of the solar system. Such structures include the PV array mounts, as well as the mounting structures of all the other system components.

### 2.1.2 Electrical maintenance

To ensure optimal system performance, you have to measure the electrical characteristics of the PV system from time to time. You must be able to carry out basic measurements using a digital multimeter.

## 2.2 General maintenance practices for PV Systems

### 2.2.1 Cleaning solar panels

* Frequency: At least once every week, or more frequently in dusty or polluted areas.
* Tools: Use soft brushes or cloths and clean water.
* Avoid: Pressure washers or abrasive materials that can damage the panels.

### 2.2.2 Inspect electrical connections

* Regularly check connections at junction boxes, inverters, batteries, and disconnect switches. Loose connections can cause overheating and system inefficiency.

### 2.2.3 Visual inspections

* Inspect the entire system visually, looking for signs of wear, damage, or corrosion. Focus on wiring, connections, fuses, and mounting structures.

### 2.2.4 Check inverter logs

* Most modern inverters have built-in monitoring systems. Regularly check the logs or display panel for warnings, errors, or irregularities in the power output.

## 2.3 Specific maintenance activities for system components

### 2.3.1 PV array maintenance

Maintenance activities for the PV arrays are generally mechanical. You will be expected to tighten bolts that fasten the array to the mounts, remove leaves that may fall on the PV array, remove dust which accumulates on the surface of the PV array, etc. Specifically, PV array maintenance activities could include:

* **Debris removal**: Periodically remove any debris, leaves or trash around the PV array. Debris presents a fire hazard as well as a drainage problem. It can lead to mildew and insect problems, ultimately causing cable damage.
* **Shade control**: Blockage from the sun results in energy loss. Therefore, you want to ensure that a solar PV array is not shaded by any natural or man-made objects. Ob- jects such as trees or shrubs, which were not present at the time of installation could be a major cause of shade. Regularly trim all plants which could cast a shadow on your PV array.
* **Soiling**: PV modules collect dust and are soiled over time, especially in arid and semi-arid regions where rainfall is infrequent. Things like bird droppings and engine emissions can also accumulate on the surface of the PV module. This can lead to a re- duction in array output of up to 20%. Therefore, periodic cleaning of the PV modules is essential.
* **Weather sealing and structural maintenance**: All equipment that is exposed to the elements should be inspected regularly for signs of weathering. Regularly inspect all points where the solar PV array is attached to a building for signs of water leakage and initiate necessary repairs immediately.

### 2.3.2 Battery bank maintenance

Battery maintenance is the most critical aspect of any off-grid or hybrid solar PV system. To maximise the battery lifespan, monthly maintenance must be carried out on the battery. Bat- tery maintenance tasks depend on a number of factors such as the type of electrolyte and manufacturer. These tasks include:

* Inspecting and cleaning the battery racks and battery terminals. Battery racks should be inspected for structural integrity and any dust removed at every maintenance in- terval. Always check for and remove any corrosion.
* Inspecting the battery disconnects, over current devices and wiring connected to the battery bank.
* Electrical protective devices are the only safeguard on the PV system to protect the user from electrocution. You must check these devices to ensure that they are fully functional.
* Measuring voltage across the bat- tery bank. The voltage flowing across a battery bank is an important indicator of the state of charge of the battery bank.
* Checking terminations and connecting cables. If the connecting cables are not firmly connected and terminated, the partial contact could result in arcing, which could melt the battery casing and lead to fire.
* Topping up the electrolyte with distilled water (wet cell/flooded lead acidbattery).

**Pre- maintenance activities**

Before you begin maintenance work on a battery bank, you must perform the following pro- cedures:

* Isolate the battery bank by disconnecting the input (supply) from the solar PV array and the output from the electrical load.
* If working on dry cell batteries, ensure that the terminals are clean.
* If working on wet cell batteries, ensure that the caps of each individual cell are tightly sealed to prevent dirt from entering the cells.
* First aid kit. Make sure that a kit is always on site and fully stocked.
* Ensure that a mixture of baking soda and water is close by when working on wet cell batteries in case of acid spills.

**Precautions to take when working with batteries**

When working with batteries, follow all relevant safety rules and regulations. These include:

* Always wear safety goggles when undertaking battery maintenance.
* If working on wet cells, wear protective gloves that are resistant to battery acid solution.
* If working on wet cells, always have a mixture of sodium bicarbonate (baking soda) and water at hand to treat acid burns.
* Always use tools with insulated handles when undertaking battery maintenance.
* Do not smoke or light a fire near batteries.

### 2.3.3 Inverter and charge controller maintenance

The inverter and charge controller are system components, which are mostly installed in- doors and which rarely have moving parts except the inbuilt cooling fan. Required mainte- nance activities include the following steps:

* Tighten all electrical connections and terminals connected to the inverter system.
* Wipe all accumulated dust from vents and surfaces using a dry cloth.
* Visually examine all indicators and displays to ensure that the PV array is charging the battery bank.
* With the use of a multimeter, measure the voltages and currents for the system com- ponents.

### 2.3.4 Maintaining cables and connections

Take care to inspect all cables in the system, ensuring that you do not omit any from your periodic maintenance. Tasks to be carried out include:

* Inspect all panels and boxes for rodent infestation and tighten all connection points.
* Inspect the efficacy of switches and breakers. Switch them on and off, looking for sparks. There should be no spark.
* Check for signs of corrosion or burning on the cables and at their connection termination points.
* Where possible, visually inspect all conduit pipes and trunkings for wear and tear.
* Ensure all grounding connections are intact.

## 2.4 Documenting maintenance activities

As a PV installation professional, you must always document all maintenance activities that you carry out on the PV system. Important documentation items include:

* **Maintenance schedule**, which shows the maintenance frequency and dates, the type of maintenance, involved components and responsible technician.
* **PV array log sheet**, which shows the maintenance date, condition of the PV array, condition of the PV array mounting structure, condition of the cabling, array output voltage and array output current.
* **Battery inspection log sheet**, which shows the date, battery serial number, condition of terminals and connections, voltage level of the batteries in the bank, and action(s) taken.

### 2.4.1 Preventive maintenance schedule

| **Daily/Weekly** | **Monthly** | **Every six months** | **Annually** |
| --- | --- | --- | --- |
| * Monitor system performance and energy output. * Check inverter display for warnings or errors. * Ensure proper operation of the water pump (if used | * Perform a visual inspection of wiring, connections, and protective devices. * Verify system grounding and lightning protection | * Clean solar panels. * Check and tighten all electrical connections. * Test insulation resistance with a Megger. * Inspect the mounting structure for signs of corrosion or loosening | * Perform a comprehensive system inspection. * Test battery health and capacity (if applicable). * Verify the performance of all protective devices (fuses, breakers, surge arrestors). * Ensure all system documentation and performance logs are up to date. |

# Troubleshooting

Over the lifetime of the PV system, some faults may develop, which you will need to diagnose and rectify. The method you choose depends on a variety of factors such as the type of fault as well as the system type and age.

Before getting into more detailed troubleshooting, talk to the system owner or operator and ask the following questions. They might provide a quick, easy answer to the problem:

* Has the weather been cloudy recently? Less sunlight means the system will generate less energy than the load consumes.
* Is the system a new installation? Failure(s) in a new system can be caused by faulty components or improper installation.
* Have there been any recent modifications to the system wiring?
* Have you added any new loads which were not part of the original system design?
* How old are the batteries?

## 3.1 PV System troubleshooting checklist

| **SN** | **Task** | **Check** |
| --- | --- | --- |
| 1 | Ask the customer when he/she first noticed the fault. |  |
| 2 | Ask the customer to explain what he/she has noticed in as much detail as possible. |  |
| 3 | Carry out a visual check of the PV system for any mechanical damage. |  |
| 4 | Ensure that you have the system circuit diagram at hand. |  |
| 5 | Check the charge controller indicator for proper functioning. |  |
| 6 | Measure voltages and current entering and leaving the charge controller and verify that the values meet design expectations. |  |
| 8 | Check the inverter indicator for proper functioning. |  |
| 9 | Measure voltages and current entering and leaving the inverter and verify that the design expectations. |  |
| 10 | Check that the terminals of the battery are properly connected. |  |
| 11 | Measure the voltage and current of the battery bank. |  |
| 12 | If working with wet cell batteries, check the specific gravity of the electrolyte. |  |

## 3.2 Common solar system faults with possible cause and solutions

| **Problems** | **Indications** | **Possible casuse** | **Solution/Troubleshooting** |
| --- | --- | --- | --- |
| **Low battery state of charge** | * **Low voltage on battery.** * **“Battery low” indicator of the charge controller is “ON”.** * **Inverter not functioning (automatic low voltage disconnect).** | Faulty connection between PV modules andcharge controller. | * Check and fix connection to PV modules. * Check breakers and disconnect switches. |
| Faulty connection between charge controller and battery | * Check for broken wires or loose connections |
| Disconnection between PV modules in array.  Disconnection in junction/combiner box | * Check module-to-module wires. * Check breakers and disconnect switches. |
| Insufficient power coming in from PV modules | * Make sure modules are clean * Check for shading. * Check all module-to-module wires; check Voc and Isc of whole array and individual modules. |
| Battery electrolyte is low | * Add distilled water to cell. |
| Defective battery or cell | * Check state of charge of each cell; if there is a significant differ- ence (>0.5 V) between cells the battery needs to be replaced (only possible for single-cell batteries). |
| Loose or corroded battery terminal | * Clean and tighten battery terminals. |
| Blown battery fuse | * Check correct rating. * Check for a short circuit. * Replace the fuse. |
| Overuse of the system | * Check and inquire about connected loads and runtime. * Leave appliance and lamps off to allow battery recharging or recharge the battrey by other means. |
| Battery will not accept charge | * Consider the battery age and history * Replace battery if old or damaged. |
| Voltage drop between module and battery too | * Calculate voltage drop. * Replace cable with higher diameter if necessary. |
| Incorrect setup of charge controller | * Consult the manual; change setup accordingly. |
| Defective charge controller | * Check operation of charge controller. * Measure voltages and currents; disconnect and reconnect. * Replace the charge controller. |
| **No solar charge** | * **Low voltage Charging indicator of charge controller remains “OFF” while sun is shining.** * **No current in cable from solar modules to charge controller** | Faulty connection between solar modules and charge controller | * Check and fix connection to solar modules. * Check breakers and disconnect switches. |
| Faulty connection between charge controller and battery | * Check for broken wires or loose connections. |
| Disconnection between modules in array.  Disconnection in junction/combiner box. | * Check module-to-module wires; check breakers and disconnect switches. |
| Thick coating of soot or dust on the module | * Clean module with water and soft cloth. |
| Broken module | * Check for broken cells, broken glass or poor connection inside module; replace solar module. |
| **No ac power on inverter output** | * **Appliances are not running.** * **Power indicator of inverter remains “OFF”.** * **Fault indicator on inverter is “ON” .** | Inverter switched off | * Locate ON/OFF switch. * Switch ON. |
| Short circuit in AC circuit or AC load | * Disconnect all circuits and loads from inverter output. * Disconnect DC input from inverter * Reconnect DC input. Check output. * Check loads and load circuits. * Reconnect AC loads one by one |
| Inverter overloaded | * Disconnect all circuits and loads from inverter output. * Disconnect DC input from inverter. * Reconnect DC input. * Check output; check power ratings of all AC loads. * Reconnect AC loads one by one. |
| Inverter overheated | * Disconnect all loads from inverter output. * Shut down inverter and allow to cool down. * Check ventilation. * Check power ratings of AC loads. * Reconnect AC loads one by one |
| Low battery voltage | * Check battery voltage. * Follow troubleshooting section “low battery state of charge” |

## 3.3 Key components maintenance and troubleshooting practices

| **Components** | **Functions** | **Maintenance** | **Problems and solution** |
| --- | --- | --- | --- |
| **PV modules (Solar panels)** | **Convert sunlight into electrical energy (DC).** | * **Visual inspection:** Regularly inspect for dirt, debris, or bird droppings that may reduce performance. Clean with water and a soft brush, avoiding harsh chemicals. * **Check for physical damage:** Look for cracks or discoloration in the glass. * **Electrical connections:** Ensure no loose or corroded connectors. | **Low power output:** Use a multimeter to check the voltage and current output and compare it with manufacturer specifications. Test under different irradiance levels and weather conditions. |
| **Mounting structure** | **Provides mechanical support and ensures optimal panel orientation.** | * **Inspect for corrosion:** Regularly check the structure for rust, especially in coastal or high-humidity areas. * **Ensure stability:** Tighten any loose bolts or fasteners. * **Check for proper tilt:** Ensure that panels are positioned at the correct angle for maximum sunlight exposure. | **Panel misalignment:** Correct any shifts in the mounting system that might affect panel alignment with the sun. |
| **Battery Bank (For Off-Grid/Hybrid Systems)** | **Stores energy for later use, particularly during nighttime or cloudy conditions.**  **Battery maintenance is the most critical aspect of any off-grid or hybrid solar PV system.** | * Inspecting and cleaning the battery racks and battery terminals. Battery racks should be inspected for structural integrity and any dust removed at every maintenance interval. Always check for and remove any corrosion. * Inspecting the battery disconnects, over current devices and wiring connected to the battery bank. * Electrical protective devices are the only safeguard on the PV system to protect the user from electrocution. You must check these devices to ensure that they are fully functional. * Measuring voltage across the battery bank. The voltage flowing across a battery bank is an important indicator of the state of charge of the battery bank. * Checking terminations and connecting cables. If the connecting cables are not firmly connected and terminated, the partial contact could result in arcing, which could melt the battery casing and lead to fire. * Topping up the electrolyte with distilled water (wet battery). | **Undercharging or overcharging:** Use a battery tester to measure voltage and state of charge. Replace if battery performance is below specifications |
| **Charge controller** | **Regulates the voltage and current coming from the PV panels to protect the battery bank** | * **Check for dust accumulation:** Wipe all accumulated dust from vents and surfaces using a dry cloth. * Keep the unit clean to prevent overheating. * **Verify operation:** Periodically check the display or indicator lights for error messages | **Battery not charging properly:** Check the output voltage and current to the battery. Inspect wiring and fuses for damage |
| **On-Grid / Off-Grid Inverter** | **Converts DC electricity from the solar panels or batteries into AC electricity for grid use or local consumption.** | * **Clean vents:** Ensure the inverter has proper airflow to prevent overheating. * **Monitor output:** Use inverter software or a monitoring system to track performance and identify issues. | **Inverter failure or grid synchronization issues:** Check for error codes on the inverter display. Measure DC input and AC output voltages. Verify grid connection and safety features |
| **Pump controller and water pump** | **Manages the operation of the water pump powered by the solar system** | * **Inspect wiring:** Check for loose connections or damaged wires between the pump controller and the water pump. * **Clean pump filters:** Regularly inspect and clean the pump’s water intake filters. | **Pump not working:** Measure voltage at the pump’s terminals. Check the controller settings and wiring connections. |
| **Fuses, Earthing, Lightning Arrestors, and Other Protective Devices** | **Protect the system from overvoltage, short circuits, and lightning strikes.** | * Inspect earthing connections: Ensure all metallic components are properly grounded. * **Check fuses:** Replace any blown fuses with the correct ratings. * **Lightning protection:** Ensure lightning arrestors are properly installed and check grounding for high-resistance faults. | **Fuse blown frequently:** Investigate short circuits or system overloads. Use a multimeter to test continuity of fuses and ground resistance. |
| **Switchgear** | **Manages power distribution and disconnects parts of the system for maintenance.** | * **Test functionality:** Periodically operate switches to ensure smooth operation. * **Inspect for wear:** Check for signs of overheating, corrosion, or mechanical damage. | **Switchgear not operating correctly:** Inspect wiring and test for continuity with a multimeter. |
| **Cables and Wiring** | **Carries DC and AC power between components.** | * **Visual inspection**: Check for damage, cracks, or exposed wires. Ensure wires are properly insulated. * **Check connections:** Make sure all terminals are tight and corrosion-free. | **Voltage drops:** Test voltage along the cable runs to ensure there are no losses due to poor connections or undersized cables. |

# Conclusion

Regular maintenance and timely troubleshooting are key to maximizing the performance and lifespan of a three-phase solar photovoltaic system. By understanding the function of each component and using systematic troubleshooting methods, you can quickly identify and resolve common issues, ensuring the system operates safely and efficiently.