Short-Course

Solar PV System Installation and Maintenance

NTQF Level III

Learning Guide -17

Unit of Competence	Install off-grid solar PV system
Module Title	Installing off-grid solar PV system
LG Code	EIS PIM3 M10 120 LO5 LG-17
TTLM Code	EIS PIM3 TTLM 0120 v1

LO 5:- Complete installation work -17

Instruction Sheet	Learning Guide:-17

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:

- Following OHS work completion risk control measures and procedures
- Accomplishing installation work without causing damage
- Ensuring final checks with plans /drawings /instructions
- Testing system operation
- Verifying installation to be compliant with standards and work specifications
- Clearing work site
- Cleaning, checking & returning tools and equipment

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Follow OHS work completion risk control measures and procedures
- Accomplish installation work without causing damage
- Ensure final checks with plans /drawings /instructions
- Test system operation
- Verify installation to be compliant with standards and work specifications
- Clear work site
- Clean, checking & returning tools and equipment

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below:
3. Read the information written in the information Sheet 1 (page: 139), Sheet 2 (page: 143), Sheet 3 (page: 149), Sheet 4 (page: 154), Sheet 5 (page: 161), Sheet 6 (page: 164), Sheet 7 (page: 166),
4. Accomplish the Self-Check 1 (page: 142), Self-Check 2 (page: 148), Self-Check 3 (page: 153), Self-Check 4 (page: 160), Self-Check 5 (page: 163), Self-Check 6 (page: 165), Self-Check 7 (page: 167),

LO 5:- Complete installation work

Information Sheet 1	Following OHS work completion risk control measures and control

1 Following OHS work completion risk control measures and control

1.1 Introduction

The next step is to finish the installation. See Figure 100 for a high level overview of the process that will be followed in Module 10. LO5 (in Yellow) deals with the completion of the installation work including testing and commissioning.

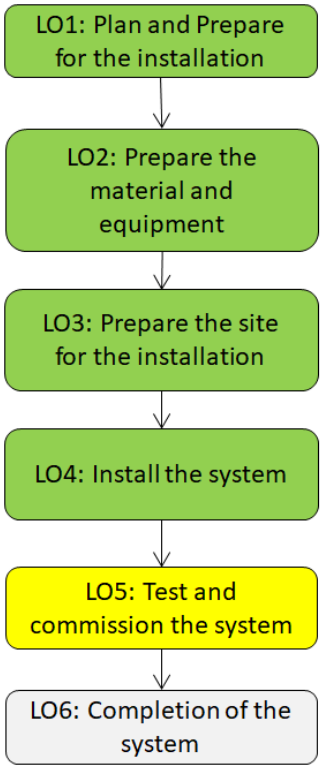


Figure 100: Installation Process

Testing and commissioning a solar system is covered in detail in Module 13 – Test and Commission Solar PV.

After the PV array and all the associated equipment have been installed, the entire system is ready to be checked out and turned on; this start up process is officially known as commissioning the system. But before you get too excited and start flipping switches, you need to make sure that everything has been installed correctly and that no obvious issues are present that can be resolved sooner rather than later.

- The full system should be tested and put in to commission before the installers leave the site.
- All safety equipment, switches and circuit breakers should be cycled and tested.

- Some controllers and inverters have a very specific hook-up sequence to bring them on-line. Be prepared to follow that sequence.
- All hard-wired loads should be operated, and all outlets should be tested.
- Restricted equipment should be locked and the keys secured.

A system description with circuit diagrams, an operations and maintenance plan, should be presented to the user.

The designer or installer should read through the operation/maintenance plan with the client, and have them sign a copy asserting that they have read the instructions. A copy of the operation and maintenance plan should be left with the client. All major components and switch gear should be labelled and be easily accessible for service.

1.2 Signage

The system installation shall include the signs as specified in IEC 62548: Design requirements for photovoltaic PV arrays. Some of the requirements for the sign are:

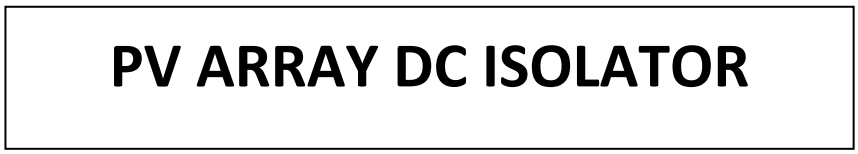
- They should be indelible and be constructed and affixed to remain legible for the life of the equipment it is attached.
- They should be legible from at least 0.8m unless otherwise specified in the relevant clause. Marking should be in the local language and understandable by the operators.

Some of the required signs are

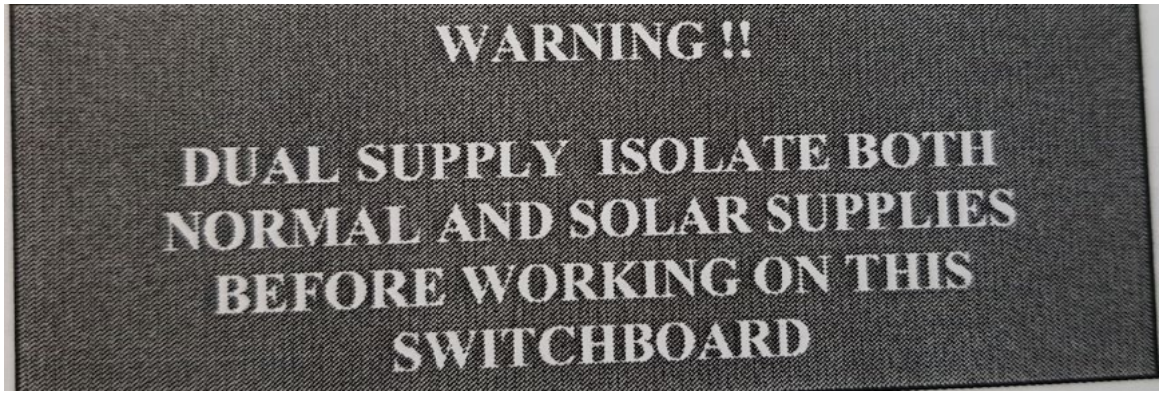
- A "**SOLAR DC**" shall be located on all PV array and PV string junction boxes.

- Sign indicating "**LIVE DURING DAYLIGHT**" shall be attached to all DC junction box and switches.

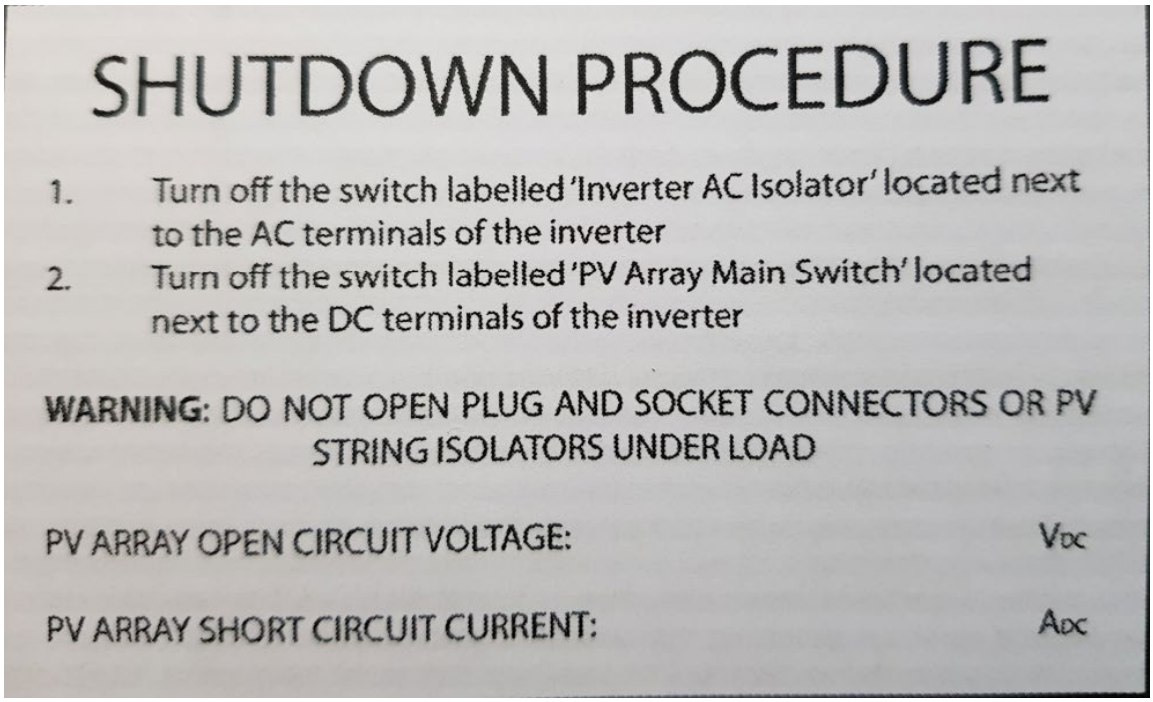
- The double pole isolator at the inverter should be labelled " **PV ARRAY DC ISOLATOR**"



- A warning sign in the switch board should be installed indicating that dual supplies exist and both normal and solar supplies should be disconnected when working on the switch board.



- A sign informing people of the shutdown procedure should be located in a prominent position. This shall state the open circuit voltage and short circuit current of the array.



Self-Check - 4	Written Test

Answer all the questions listed below. Use the Answer sheet provided in the next page:

N°	Questions and answers
1	**Write some of the signage you should put at the installation site.**

Satisfactory	4 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = _____

Rating: _____

Name

Date

Information Sheet 2	Accomplishing installation work without causing damage

2 Accomplishing installation work without causing damage

Always follow the supplier procedures when installing PV system components. To prevent causing damage to the installations, always use:

- The correct tools for the job.
- The correct handling of the equipment.
- The correct installation procedure as per manufacturer's specifications.
- The correct safety equipment.

PV Modules are particularly prone to damage caused by bad handling. Micro cracks in solar cells are a genuine problem for PV modules. Improper handling of modules during transportation, unpacking, storage and installation can cause various cracks inside the module.

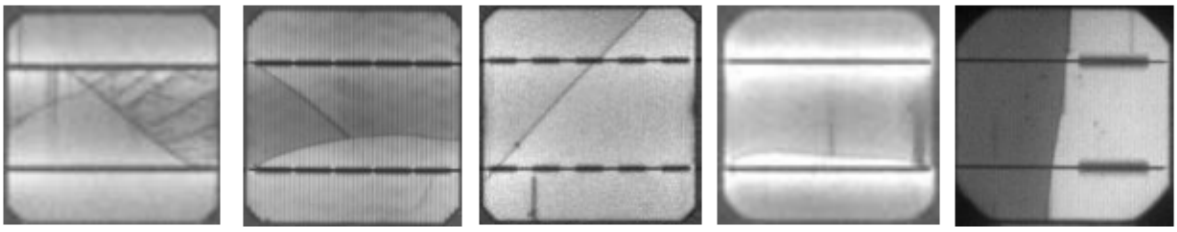


Figure 101: Micro cracks

The following precautions should be taken:

- Two people should carry modules. Do not carry on your head or back.
- Place modules down on a protected surface with the glass facing down.
- Wear gloves when handling modules.
- Do not put objects on the module or modules on top of each other without protective material.
- Do not lean modules against something. A gust of wind may blow the module over.
- Do not walk on modules.

Figure 102: Carrying modules

Figure 103: Wrong way to carry a module

Figure 104: Do not walk on modules

TASK	RISKS	PREVENTATIVE MEASURES
Manual Handling of Modules	Falling objects during handling	- Use of safety shoes
		- Avoid distraction
	Hitting standing/moving objects	- Avoid distraction
		- Neat and tidy work area
	Cuts	- Use of safety gloves
		- All cutters or other type of bladed implement should be a safety version
	Overexertion and back injuries	- Training and information to workforce regarding the correct way to handle loads and the potential risks (according to the laws of the country in question)
		- Whenever possible use mechanical lifters
	Tripping	- Avoid distraction
		- Use of safety shoes
		- Neat and tidy work area
	Physical tiredness	- Take rest as necessary according to risk evaluation
Mechanical Handling of Modules (forklift truck and loading bays)	Accidents involving vehicles	- Signposting the loading area and warehouse as required by law of the country in question.
		- Only use the lanes signaled and set aside for vehicle movement, ensuring that visual and audio warnings are clear.
		- Regular servicing of vehicles (as necessary in EU,NA & MOW and according to the law of the country in question)
		- Employees should receive necessary training before using such equipment.
	Objects falling through collapsing or slippage	- Keep surfaces in good repair, avoiding slippery areas or non-uniformity
		- Respect maximum loads for all equipment
	Pallets falling during handling	- As the measurements of the pallets are above Standard size, it is recommended that extensions are used to help stability. (at least ***1,6m*** or ***1.9m*** long)

Figure 105: Extract from Risen PV Modules Instructions

2.1 Safety

As with any activity, Safety is a full time job and is the responsibility of everyone working with PV systems, whether in the design, installation or maintenance.

To work Safely, You must have:

- Good work habits
- A clean and orderly work area
- Proper equipment and training in its use
- An awareness of potential hazards and how to avoid them
- Periodic reviews of safety procedure; and
- Instruction in cardio- pulmonary resuscitation (CPR) and basic first aid.

It is recommended that all employers adopt a six step approach towards safety:

- Develop and OHS policy
- Consult with employees and outside organisation
- Provide information and training
- Identify and assess hazards
- Implement and follow risk control measures
- Maintain and improve an OH&S program

2.1.1 Electrical Hazards

Photovoltaic (PV) devices generate electricity, and they should always be considered electrically “live”. They generate electricity as long as light falls on them. Attempting to cover them, using a blanket or cardboard for example, is not a safe practice. Light could still reach the PV module, or the covering could come off. In many PV systems, the voltage level I dangerous and any installation or maintenance work must be undertaken with extreme care. The output of the inverter is 230V AC, Which I a potentially deadly voltage. It is important that all electrical interconnections between the inverter and the switch board are undertaken by a licenced electrician.

2.1.2 Battery Safety considerations

Due to the hazardous materials and chemicals involved, and the amount of electrical energy where they store, batteries are potentially dangerous and must be handled and used with caution. Typical batteries used in a stand-alone PV systems can deliver up to several thousand amps under short-circuit conditions, requiring special precautions. Depending on the size and location of a battery installation, certain safety precautions are be required.

2.1.3 Safety Equipment

Personal Safety Resources

- A work partner(never work alone)
- An understanding of safety practices, equipment and emergency procedures

- Safety checklists
- Safety helmet & eye protection
- Appropriate safety harnesses, if working on roofs or other elevated sites
- Proper measuring equipment: electrical an dimensional
- Tape and use wire nuts or cable connectors on end of cables

Job Site Safety Resources

- Safety plan & first aid kit
- Fire extinguisher
- Appropriate ladders
- Appropriate lifting equipment
- Suitable labels on all equipment, wiring, etc.

Self-Check - 5	Written Test

Answer all the questions listed below. Use the Answer sheet provided in the next page:

N°	Questions and answers
1	List personal 4 safety resources.

Satisfactory	4 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = _____

Rating: _____

Name

Date

Information Sheet 3	Ensuring final checks with plans/ drawings /instructions

3 Ensuring final checks with plans/ drawings /instructions

3.1 Introduction

Before activating the PV system, there should be a visual inspection. The following should be verified (Crawley, 2016):

- Verify the supply and installation of the entire equipment and devices.
- Verify the quality of material.
- Verify labelling and identification of PV modules.
- Verify the peak power installed.
- Inspect and Verify front and rear side of PV modules for surface damage, fastening).
- Shading of modules.
- Optimal tilt and orientation of PV modules.
- Verify Supporting structure.
- Verify DC Electrical connections.
- Verify proper installation of the earthing and over voltage protection.
- AC electrical connection.
- Cleanness of the installation.

3.2 Detailed Checking and Verification

The following paragraphs were adapted from (Mayfield, 2010)

(Mayfield, 2010)

3.2.1 Mechanical Elements

You need to ensure that the mechanical portion of the system is what you expect and that it can keep the array in place.

- Footings (i.e. the method to keep the array in place)
  - For rooftop arrays, are the footings installed in the proper locations and with the proper spacing?
  - Was the correct hardware used in the installation of the footings?
  - For ground-mounted arrays and top-of-pole arrays, were the holes dug to the proper dimensions? Was the concrete poured high enough? Is the spacing between poles correct?
- Racking (Rails and clamps)
  - Are the modules properly connected to the racking system with the correct hardware?

- Are the modules grounded to the racking system the way they should be (with grounding clips or an equipment-grounding conductor attached to each module).
- Is the racking system properly attached to the footing system?

3.2.2 Electrical Elements

As you examine your PV system, you have to look at all the electrical components to verify that everything was installed correctly.

- **PV Modules**
  - Is the correct number of modules installed?
  - Is the manufacturer and model number the same as it is on the plans drawn up for the permitting process?
  - Are the modules wired in the correct string configuration? This configuration can be series, parallel, or series-parallel.
- **Batteries**
  - Are the batteries properly vented to the outside? All batteries release hydrogen, although sealed batteries release very little of it.
  - Are the batteries installed in a proper enclosure? The batteries should be protected from damage and anyone who may hurt themselves in their presence.
  - Are the batteries installed and wired properly? The system will require a very specific battery voltage, and if the batteries aren't wired right, the system won't work.
- **Charge Controller(s)**
  - Is the charge controller installed in a proper location? It's typically mounted very near the inverter and battery bank.
  - Are disconnecting devices and overcurrent protection devices present on both the input and output sides of the controller?
  - Are the correct wire gauges attached to the controller?
- **Inverter(s)**
  - Does the inverter's output voltage match the utility grid voltage? Some inverters only connect to a single utility voltage, whereas others allow you to field-select the voltage. Either way, the inverter and utility voltages need to be verified.
  - Is the inverter installed according to manufacturer recommendations?
  - Inverters are often installed without the necessary clearances for proper cooling and access.
  - Is the inverter mounted in the best location? Is it installed in the direct sun? Is there airflow for the inverter to dissipate heat? All inverters are negatively affected by heat, so try to keep them as cool as possible.
  - Does the inverter's voltage window match up with the installed array correctly? This syncing of voltage windows really should've been addressed

during the design process, but it's worth examining in the field anyway just to be safe.

- **Conductors**
  - Is the correct conductor type used for the installed environment? For example, is the conductor used along the array appropriately rated for exposure to high temperatures and sunlight? Does the conductor used in the conduit have the appropriate ratings for the locations in which it's installed?
  - Is the wire size specified in the plans what's actually installed?
  - Are there signs of potential wire damage from installation? If any conductors look like they may have been pinched or appear damaged from being pulled through the conduit, note that so you can investigate.
  - Is the color-coding correct?
  - Is the PV source circuit wiring properly supported?
- **Conduit**
  - Is the correct conduit used? Some locations may require metallic conduit, whereas others may allow PVC.
  - Is the conduit supported correctly?
  - Have expansion fittings been installed? Conduit, especially PVC, expands and contracts with changes in temperature.
- **Disconnect devices**
  - Are the disconnect devices installed according to local regulations? Can you disconnect the PV array and AC power out of the inverter, and are these disconnect devices grouped together?
  - If the utility requires a visible, lockable disconnect, is it installed correctly according to the utility's requirements?
  - Are the correct conductors being disconnected in each disconnecting device?
  - Are the installed disconnect devices properly rated for their environment and for the voltage and current values they'll be carrying?
  - Are the proper labels installed on the disconnect devices?
- **Overcurrent Protective Devices (OCPD)**
  - Are the current ratings correct for the circuit? An incorrectly sized
  - OCPD (either too big or too small) will cause problems.
  - Do the OCPDs have the correct voltage ratings? This is crucial, especially on the PV source circuits. The OCPDs must have the proper DC ratings, or else they won't be able to properly protect the system when they're really needed.
  - Are the OCPDs in good condition? A fuse or circuit breaker that's faulty on day one can lead to a number of hours in troubleshooting. To verify whether an OCPD is able to pass current when the system is turned on, perform a continuity test.

After examining the system to verify that all the mechanical and electrical elements have been installed correctly and safely, then you are ready for commissioning.

Self-Check - 6	Written Test

Answer all the questions listed below. Use the Answer sheet provided in the next page:

N°	Questions and answers
1	**Which electrical checks should we do after the installation? (6)**

Satisfactory	6 points
Unsatisfactory	Below 6 points

Answer Sheet

Score = _____

Rating: _____

Name

Date

Information Sheet 4	Testing system operation

4 Testing system operation

4.1 Introduction

The system is now ready to be tested and commissioned.

4.2 Charge Controller System

The explanation below refers to Figure 106.

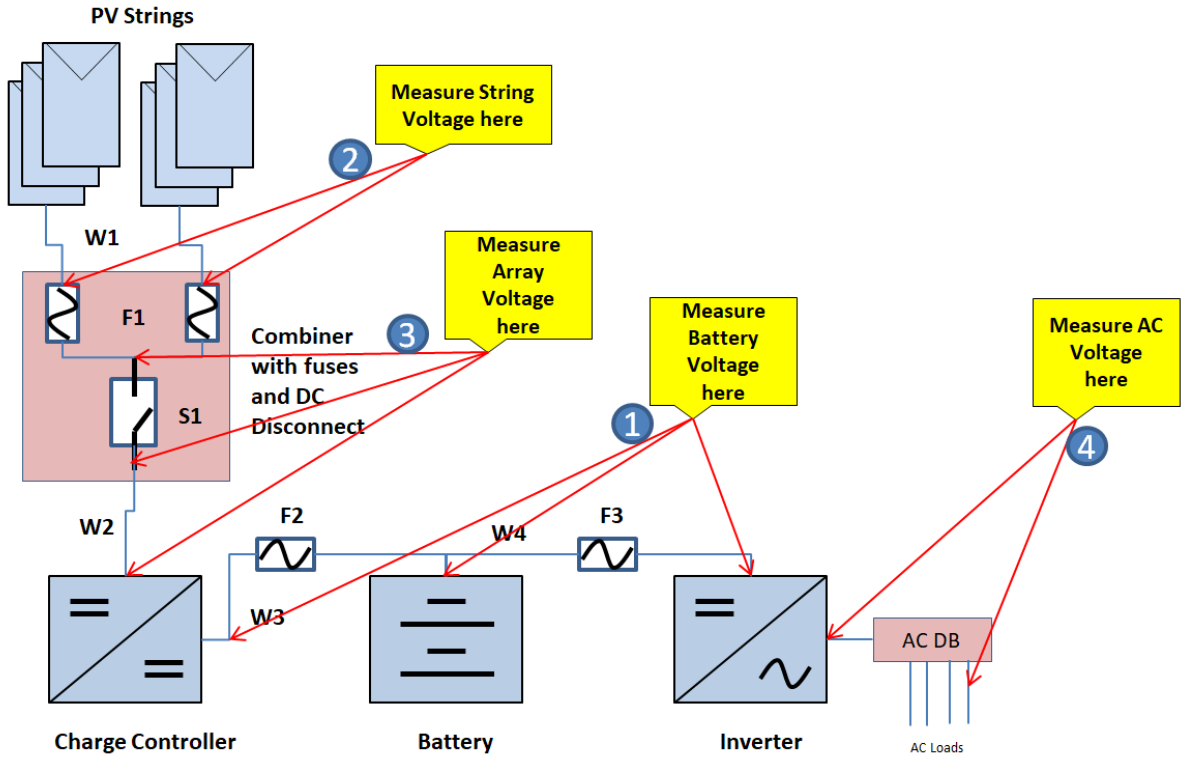


Figure 106: Voltage measuring points

- **Verify that disconnects are in the open position, locked off, and fuses are out.**
- Coordinate with all other employees on the job site so that all personnel are aware that the system is going to become energized, and wear appropriate PPE.
- Connecting the PV source circuit leads to the DC homerun will energize the DC side of the system up to the point of the first open disconnect or fuse.
- Electrically insulated gloves and safety glasses must be worn for these tests, as the equipment is now energized.
- Make sure that the digital multimeter (DMM) is set to the appropriate setting to prevent a false reading (DC/AC Voltage and peak hold off).

4.2.1 Test DC Voltage and Polarity of battery (1)

- Measure the DC voltage on the battery terminals and ensure that the voltage is correct.
- Make sure that the polarity is correct.
- Measure the same voltage and polarity at the fuse disconnect and at the inverter input;
- Make sure that the cable polarity is correct to the charge controller;
- Switch on the charge controller **(PV circuits not connected yet);**
- Observe that the Charge Controller switch on correctly and indicates the battery symbol or indicator (Figure 107).

4.2.2 Test DC voltage and Polarity of PV system (2 & 3)

- Confirm the voltage and polarity of the PV source circuit(s) up to the combiner box.
- An expected open-circuit voltage (Voc) reading can be estimated based on the module specs and the number in series. Remember, the voltage will be lower if the modules are hot from being in sun.
- Insert fuses (F1)
- Measure the combined voltage of the strings in the combiner box before S1.
- Before switching on the DC isolator (S1), confirm that the DC voltage measured before the isolator is lower than the maximum input voltage of the charge controller;
- If the voltage is correct, switch on the isolator and measure the voltage at the charge controller.
- Ensure that the charge controller indicates that the PV is connected and charging the battery (Figure 110)

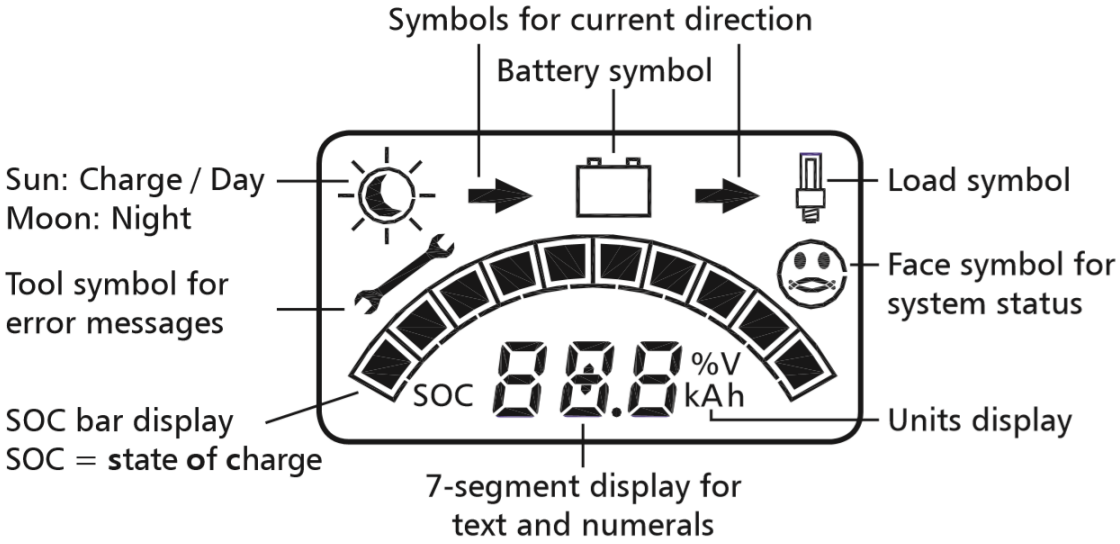


Figure 107: Display Window of a Steca Charge Controller (Source: manual Steca PR 3030)

4.2.3 Test AC voltage (4)

- Voltage is tested line to line and from each line to neutral. On a typical 240 Vac system the line reading will be around 240 volts.
- Polarity doesn't apply on the AC side.
- Test at the output of the inverter.
- If the voltage is correct, switch on the circuit breakers for the different circuits and confirm if the voltage is available at all the output circuits.
- in each accessible point, remove the lock, replace the cover, switch it on, and test at the next point;
- Make sure that the power is available at all the outlets, lights and fixed appliances.

4.2.4 Start-up procedure

The array voltage and polarity and the AC voltage have been tested and confirmed to match the system operating specification. The description above is general – always consult the equipment installation manual for special startup sequences and procedures.

4.3 Hybrid Inverter System

The explanation below refers to Figure 108.

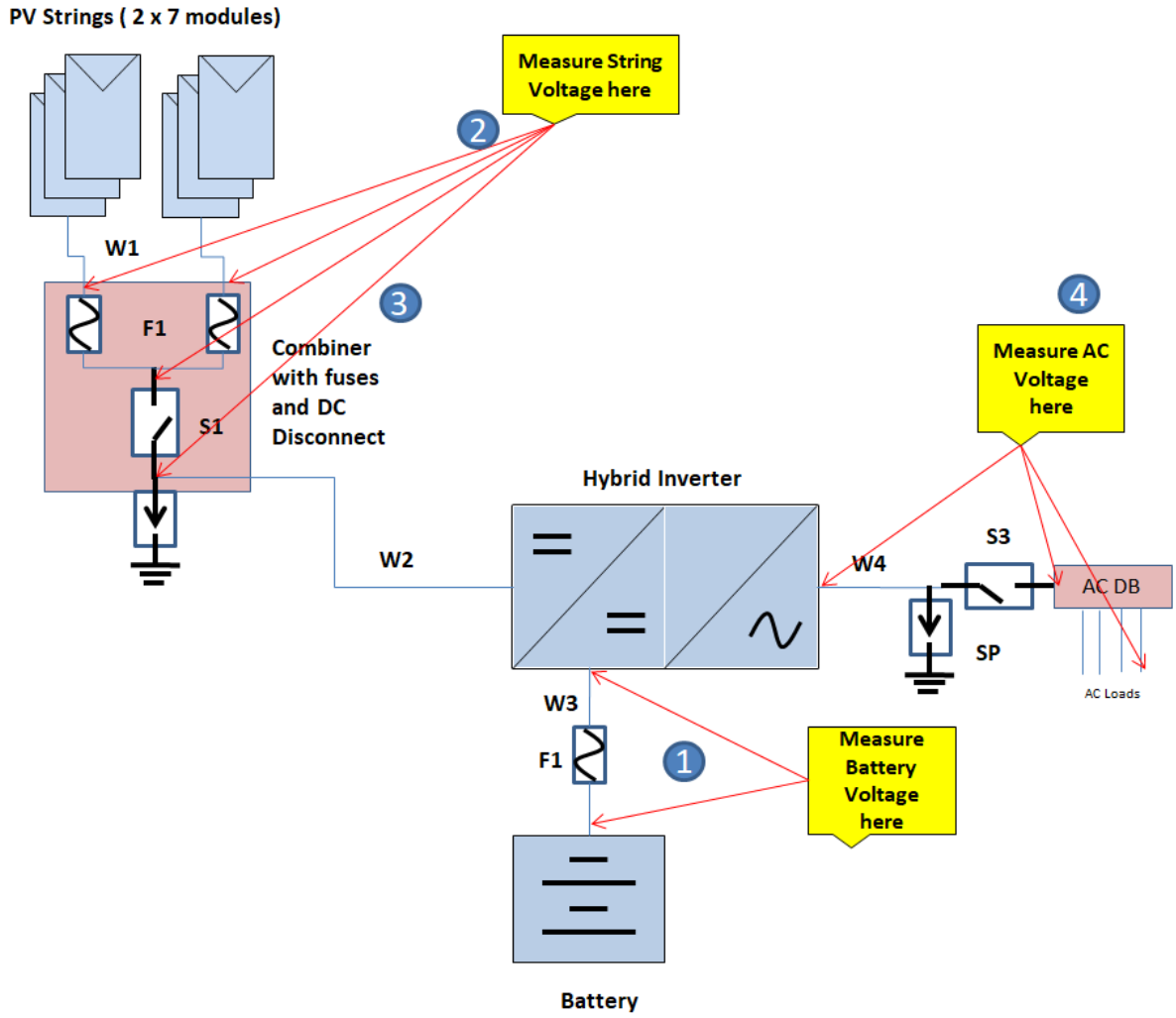


Figure 108: Hybrid Inverter testing

- **Verify that all disconnects are in the open position, locked off, and fuses are out.**
- Coordinate with all other employees on the job site so that all personnel are aware that the system is going to become energized, and wear appropriate PPE.
- Connecting the PV source circuit leads to the DC homerun will energize the DC side of the system up to the point of the first open disconnect or fuse.
- Electrically insulated gloves and safety glasses must be worn for these tests, as the equipment is now energized.
- Make sure that the digital multimeter (DMM) is set to the appropriate setting to prevent a false reading (DC/AC Voltage and peak hold off).

4.3.1 Test DC Voltage and Polarity of battery (1)

- Measure the DC voltage on the battery terminals and ensure that the voltage is correct.
- Make sure that the polarity is correct.

- Measure the same voltage and polarity at the fuse disconnect (F1) and at the inverter input;
- Make sure that the cable polarity is correct to the inverter;
- Switch on the inverter **(PV circuits not connected yet);**
- Observe that the inverter switch on correctly and indicates the battery symbol or indicator (Figure 109).

4.3.2 Test DC voltage and Polarity of PV system (2 & 3)

- Confirm the voltage and polarity of the PV source circuit(s) up to the combiner box.
- An expected open-circuit voltage (Voc) reading can be estimated based on the module specs and the number in series. Remember, the voltage will be lower if the modules are hot from being in sun.
- Before switching on the DC isolator (S1), confirm that the DC voltage measured before the isolator is lower than the maximum input voltage of the inverter;
- If the voltage is correct, switch on the isolators (S1) and measure the voltage at the inverter.
- Ensure that the inverter indicates that the PV is connected and charging the battery (Figure 109)

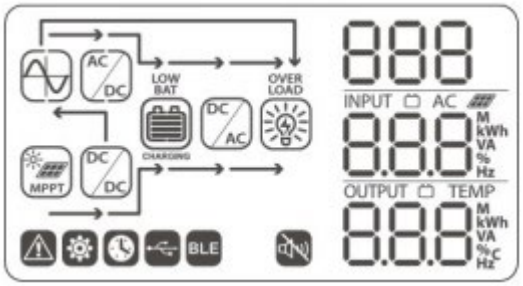


Figure 109: Hybrid Inverter Display (Phocos Anygrid)

4.3.3 Test AC voltage (4)

- Voltage is tested line to line and from each line to neutral. On a typical 240 Vac system the line reading will be around 240 volts.
- Polarity doesn't apply on the AC side.
- Test at the output of the inverter.
- If the voltage is correct, switch on the AC Isolator (S3) and confirm that the voltage is correct at the top of the circuit breakers for the loads;
- Switch on circuit breakers and confirm if the voltage is available at all the output circuits.
- In each accessible point, remove the lock, replace the cover, switch it on, and test at the next point;
- Make sure that the power is available at all the outlets, lights and fixed appliances.

4.3.4 Start-up procedure

The array voltage and polarity and the AC voltage have been tested and confirmed to match the system operating specification. The description above is general – always consult the equipment installation manual for special startup sequences and procedures.

Self-Check - 7	Written Test

Answer all the questions listed below. Use the Answer sheet provided in the next page:

N°	Questions and answers
1	**What does DMM stand for?**
1	**Explain the voltage measuring points on a charge controller off-grid system (10)**

Satisfactory	8 points
Unsatisfactory	Below 7 points

Answer Sheet

Score = _____

Rating: _____

Name

Date

Information Sheet 5	Verifying installation to be compliant with standards and work specifications

5 Verifying installation to be compliant with standards and work specifications

5.1 Introduction

After testing, ensure that all the tasks previously defined are checked off the list. Your own checklist or a checklist guided by the RAL acceptance document discussed in Module 13, LO1.

Table 10: Verification Checklist Sample

S/N	System component to be identified	Check if it is fulfilled or not fulfilled		Evaluation conditions (Example)
1	Solar PV Modules			
	Installed module type:	Fulfilled	Not fulfilled	Fulfilled if all are installed; state capacity *Additional comments in case of defects (e.g. spots and others)*
	Installed capacity:	Fulfilled	Not fulfilled	State make and model as per manual Fulfilled if as per specification.
2	Inverter			
	Installed Inverter type:	Fulfilled	Not fulfilled	Fulfilled if installed even if defect; In case of defects: additional comment
	Installed capacity:	Fulfilled	Not fulfilled	State make and model as per manual Fulfilled if as per specification
3	Charge controller			
	Installed charge controller type:	Fulfilled	Not fulfilled	Fulfilled: if installed even if defect In case of defects: additional comment
	Installed capacity:	Fulfilled	Not fulfilled	State make and model as per manual Fulfilled: if as per specification
4	Battery system			
	Installed battery type:	Fulfilled	Not fulfilled	Fulfilled: if battery voltage and capacity meets contract (eg. total 48 V/3000 Ah specified). State voltage (V) and recorded time (hh:mm) as per Measurement Sheet Fulfilled: eg. if >50VDC, if 48-50VDC (but with additional comments since voltage should be higher) Not fulfilled: if measurement <48VDC
	Installed capacity:	Fulfilled	Not fulfilled	State make and model as per manual Fulfilled: if as per specification
5	Balance of system			
	Electric wiring as specified:	Fulfilled	Not fulfilled	As per Technical Sheet Not fulfilled: in case of obvious deviations (incorrect cables types)

Self-Check - 8	Written Test

Answer all the questions listed below. Use the Answer sheet provided in the next page:

N°	Questions and answers
1	What will you do if you find broken panel when you open the package?

Satisfactory	2 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = _____

Rating: _____

Name

Date

Information Sheet 6	Cleaning work site

6 Cleaning work site

After installation, the work site should be cleared of all tools, debris and waste.

- Waste material is transferred to designated storage area.
- Work areas and worksite are cleaned.
- Vermin and pests are controlled.
- Housekeeping tasks are completed and any problems reported to supervisor.
- Worksite is monitored regularly to ensure it complies with food hygiene and OHS requirements and workplace procedures.

6.1 Implement the 5S rule

- **Sort** (Separate, Scrap, Sift)
  - Discard items that are clearly no longer use.
  - Evaluate items that are potentially unnecessary.
- **Straighten** (Set in order, Store, Simplify)
  - Arrange necessary items for better work flow.
  - Create visual order.
- **Shine** (Scrub, Sweep)
  - Determine target areas for cleaning and inspection.
  - Assign cleaning or inspection duties.
  - Establish a cleaning or an inspection method.
  - Carry out cleaning or inspection.
- **Standardise**
  - Create standards to make sort, straighten and shine habit.
- **Sustain**
  - Establish and implement a 5S internal audit system.
  - Implement 5S initiatives for continued employee engagement.

Self-Check - 9	Written Test

Answer all the questions listed below. Use the Answer sheet provided in the next page:

N°	Questions and answers
1	Mention some of cleaning work site activities

Satisfactory	4 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = _____

Rating: _____

Name

Date

_____

Information Sheet 7	Cleaning, checking, & returning tools & equipment

7 Cleaning, checking, & returning tools & equipment

Tool housekeeping is very important, whether in the tool room, on the rack, in the yard, or on the bench. Tools require suitable fixtures with marked locations to provide an orderly arrangement. Returning tools promptly after use reduces the chance of it being misplaced or lost. Workers should regularly inspect, clean and repair all tools and take any damaged or worn tools out of service.

Use the tools check list you used at the beginning of the work.

Self-Check - 10	Written Test

Answer all the questions listed below. Use the Answer sheet provided in the next page:

N°	Questions and answers
1	Why is tools housekeeping important?

Satisfactory	2 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = _____

Rating: _____

Name

Date