

Short-Course

Solar PV System Installation and Maintenance

NTQF Level III

Learning Guide -19

Unit of Competence	Diagnose, Repair and Maintain PV System
Module Title	Diagnose, Repair and Maintaining PV System
LG Code	EIS PIM3 M15 0120 LO1-LG19
TTLM Code	EIS PIM3 TTLM 0120v1

LO1: - Plan and prepare for troubleshooting activities-19

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

- Obtaining work requirements
 - Planning and sequencing work
 - Prepare for troubleshooting of solar PV systems
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- 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: -
 - Obtain work requirements
 - Plan and sequence work
 - Prepare for troubleshooting of solar PV systems

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: 3), Sheet 2 (page: 5), Sheet 3 (page:8), Sheet 4 (page: 12), Sheet 5 (page: 14), Sheet 6 (page:18), Sheet 7 (page: 20), Sheet 8 (page: 22)
4. Accomplish the Self-Check 1 (page: 4), Self-Check 2 (page: 7), Self-Check 3 (page:11), Self-Check 4 (page: 13), Self-Check 5 (page:17), Self-Check 6 (page: 19), Self-Check 7 (page: 21), Self-Check 8 (page: 27)

LO1. Plan and prepare for troubleshooting activities

Information Sheet 1	Obtaining work requirements from request/work orders or Customer's complaint
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1 Obtaining work requirements from request/work orders or Customer's complaint

The diagnosing and repair of a PV system will usually start with a call from the customer complaining that either:

- There is no power
- There is low power

Before starting the work and rushing to site, it is most important to fully understand the problem and to plan the requirements and further procedures for the task at hand.

To understand what to do, as much information as possible should be collected to be prepared to what to expect on site (what, how, why, which method to use?)

Possible questions to ask either the client or the project leader are:

- What kind of error has occurred?
- Under what conditions did the error occurred?
- Does the system still work?
- Who discovered it?
- Since when does the system not work? Or when did the error occur first?
- Are there any error codes displayed on the charge controller or inverter? What error codes?
- Did the client do anything to try to fix the error?

From the above, the work requirements can be formulated.

It is advised to take notes to share information with co-workers and have a full documentation of the case.

Self-Check - 1	Written Test
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Instruction: Follow the below selected instruction

Answer all the questions listed below:

N°	Questions and answers
1	Name 3 questions to ask when a fault is reported:

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = _____
Rating: _____

Name

Date

Information Sheet 2	Planning work in detail and in prioritizing for the diagnosis and repair of the system
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2 Planning work in detail and in prioritizing for the diagnosis and repair of the system

Go through all the steps of fault finding and repairing of a PV system as described in LO 60 and LO 61 and prepare a detailed work plan. Use the plan to prepare for the job and not to forget to pack anything or to perform any step while on site.

2.1 Example of a work plan:

	Work step: What?	Implementation: How?	Reason: Why?	Notes
1	Plan work in detail	See LO1	To know what to prepare for	
1a	Gathering information on the case	Ask supervisor and client what happened, check documentation	To decide what tools and spares to take to site and have background knowledge that helps finding the fault	Read manuals of the system's components
1b	Pack materials to take on site	Make a tick list to not forget anything	To be prepared for every eventuality	Take spares for all equipment on site if possible. Include all manuals and troubleshoot guides. Include PPE.
1c	Check functionality of multimeter and other equipment	Switch on and do test measurement	Make sure it is operational	Take spare batteries
1d	Make sure from manufacturer if there are any firmware updates	Contact supplier of equipment	To do an update while on site. There may be updates related to the problem	

	Work step: What?	Implementation: How?	Reason: Why?	Notes
1e	Ask the supplier support for guidance on the problem reported	Contact supplier of equipment support	They may know of the problem and what is required to fix it	
2	Find the Fault	See LO2	To identify what is wrong	
3	Repair or Rectify	See LO3	To repair the system	
4	Test the system	See LO4	To test if everything is working as designed	
5	Debrief the customer	See LO5	To update the customer on what was done	
6	Complete the work	See LO6	To update all documentation and clear everything on site	

Self-Check - 2	Written Test
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Instruction: Follow the below selected instruction

Answer all the questions listed below.

N°	Questions and answers
1	Name 3 things to do when planning the work:

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = _____

Rating: _____

Name

Date

Information Sheet 3	Selecting and Interpreting relevant plans, drawings and texts
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3 Selecting and Interpreting relevant plans, drawings and texts

Check the documentation or technical description of the system that was prepared when the system was installed. Important questions to ask are:

- What kind of system was installed? Off-grid? Grid-connected? Something else?
- What components were used? Manufacturer and model?
- How is the system connected in the house? Is there a wiring plan?
- Are there any spares on site?

A wiring diagram can help planning the steps of work. It shows where to find which parts of the system, how they are connected, which protection units were used and how to isolate certain parts when troubleshooting and testing. It will also guide what spares need to be taken.

Another important resource is the data sheets and manuals of the components. Data sheets e.g. contain information on nominal voltage of a component which helps you to confirm if the component is working correctly when testing it with a multimeter.

The manual of a component contains detailed information on performance, installation and trouble shooting. Especially when checking more complex components like programmable charge controllers or inverters, the manual can help to find and correct faults.

Plans, wiring diagrams, data sheets and manuals should be taken on site for the repair, either printed or as digital version.

It is important for the technician(s) that will do the testing and repairing to fully understand the design and to be able to interpret the electrical drawings:

- This will help them to see if the installed system complies with the design
- They will understand the system layout, disconnect devices and nominal parameters to test against better
- They will be able to update the as-build drawings

The following information should be obtained:

- System Data
- Wiring diagram or electrical drawings
 - Block diagrams
 - Circuit drawings
 - Single-line diagrams (SLD)
 - Schematic diagrams
- Data sheets of all installed equipment
- Test results and commissioning data

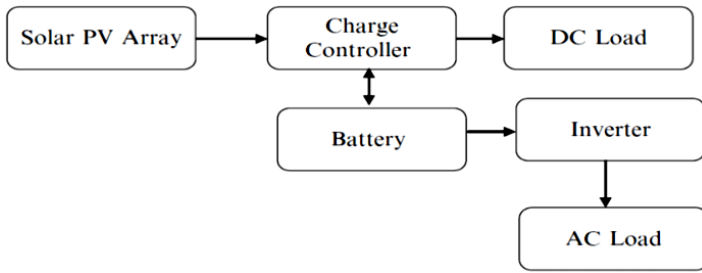


Figure 1: Example Block Diagram

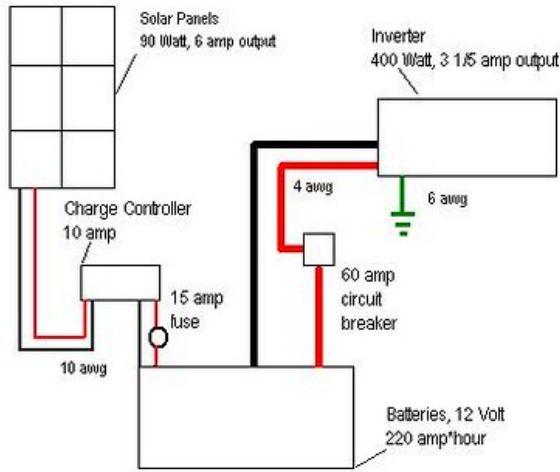


Figure 2: Simple schematic diagram (<https://www.flickr.com/>)

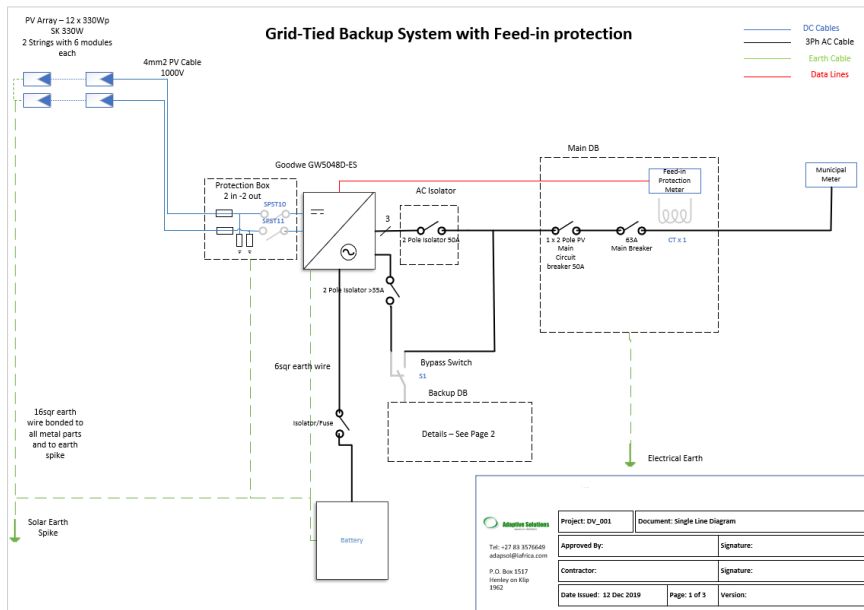


Figure 3: Example SLD

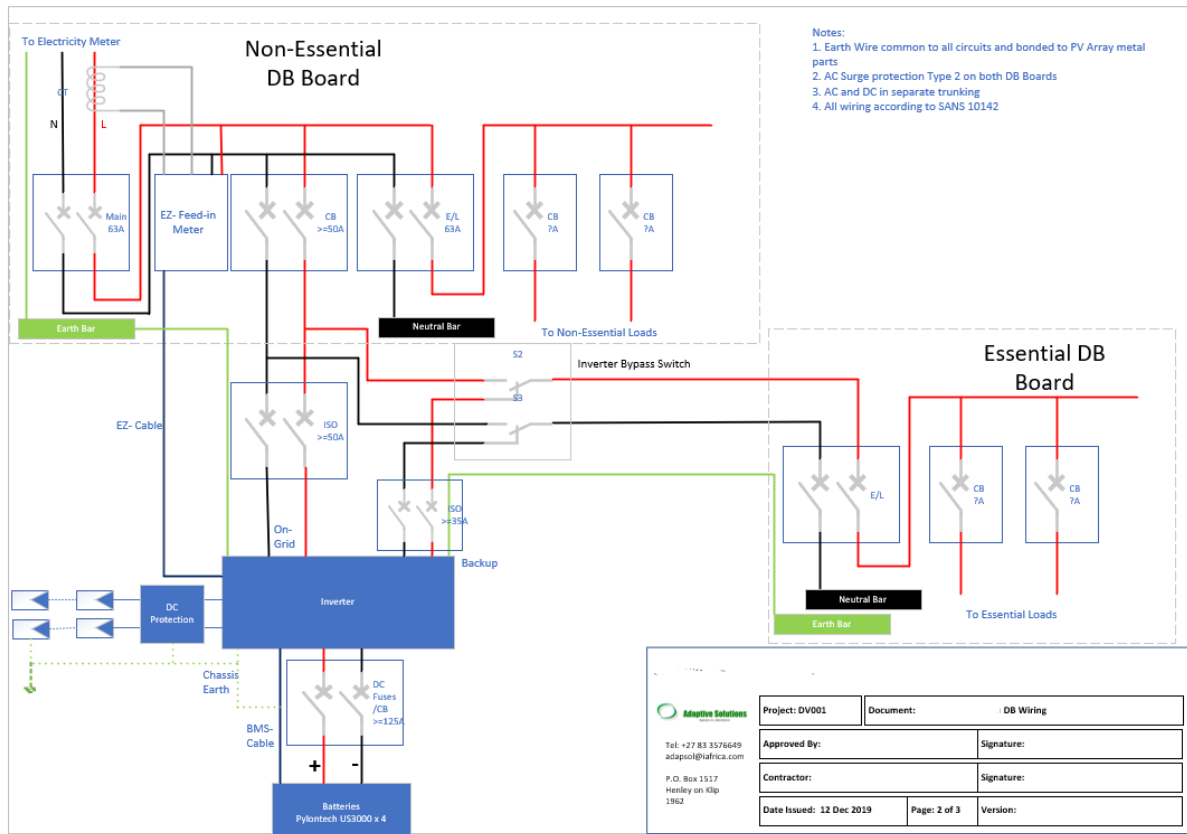


Figure 4: Example circuit drawings

Self-Check - 3	Written Test
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Instruction: Follow the below selected instruction

Answer all the questions listed below

N°	Questions and answers
1	What can be learned from a wiring diagram? Name 3 things.
2	Name two other items to take to site (2)

Note: the satisfactory rating is as followed

Satisfactory	4 points
Unsatisfactory	Below 3 points

Answer Sheet

Score = _____
Rating: _____

Name

Date

Information Sheet 4	Filling troubleshooting checklist for maintenance and customer complaint
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4 Filling in troubleshooting checklist for maintenance and customer complaint

For every troubleshooting activity and maintenance, a checklist and protocol should be prepared. The protocol serves several purposes.

4.1 Solar Installation Company

For the solar installation company, the protocol is needed to:

- Keep track of the work that was carried out to understand future errors
- Inform colleagues of what happened in case someone else takes over the site
- Count the material that was used to order new parts and invoice the client
- Have the client sign the protocol to confirm that the system was operational again when the installer left. It helps to avoid conflicts with the client when the system fails again.

4.2 Client

For the client the protocol serves to:

- Have information about what the installers did
- Understand the price that is charges for repair, materials, and spare parts
- Have a complete documentation of works and faults in case he wants to change to another solar company in the future

4.3 Protocol

A troubleshooting or maintenance protocol should contain information on everything that happened on site:

- Causes of the fault
- Fixing procedure
- Parts replaced
- Changes in wiring etc.

After the job is finished, the system documentation should be updated. Wiring diagrams should be updated, and data sheets of new components should be saved if any changes were made.

Self-Check - 4	Written Test
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Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	Questions and answers
1	A troubleshooting or maintenance protocol should contain information on everything that happened on site.
	True or false:
2	For the client, the troubleshooting checklist should not have too much detail because he may go to another supplier.
	True or false:

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = _____

Rating: _____

Name

Date

5 Outlining sequence of troubleshooting activities

The troubleshooting method depends upon the type of fault and the type of PV system. The general procedure for all troubleshooting activities is the following:

- **Ask the clients when and how they noticed the fault.** The fault may occur under certain conditions e.g. the inverter trip when a pump is switched on. Also, circuit diagrams and the technical description of the system should be checked for better understanding.
- **Do a visual check of the PV system.** Especially check the PV array to see if there is any mechanical damage and soiling. Wiring and electrical connections should also be checked. Look out for burn marks or visual damage.
- **Try to isolate the fault by using an exclusion procedure.** Narrow down the possibilities of the cause for the fault step by step. Try to identify where the fault is located before you go into detailed inspection of components. You do not want to dismantle the PV array to measure the performance of every single module before you made sure that the fault cannot be somewhere else.

Depending on the type of fault set up a work plan of which components to check. The manuals of the components mostly contain a chapter on troubleshooting which should be used when planning and conducting the diagnosis.

The following graphic shows an example on how to narrow down the possible causes for an error when the system is not supplying power.

A good starting point will be the commissioning checklist as described in Module 13.

General Information

Site address _____
 Your name _____
 Date _____
 Time _____
 Currently producing (Watts) _____ (total from all inverters)
 System peak Watts _____ (STC rating)
 Inverter manufacturer _____
 Inverter model number _____
 Inverter serial number _____
 Currently producing (Watts) _____
 Utility meter number _____
 Module manufacturer _____
 Module model number _____
 Actual grid voltage L1-L2: _____
 (Measured at point of interconnection) L1-N: _____ L2-N: _____

Array Information

	Array A	Array B	Total
Array true bearing/azimuth (degrees)			—
Array tilt (degrees)			—
Inverter quantity			
Module quantity			

Component Numbers and Inverter Production

Performance Verification Back of module temp: _____
 Solar irradiance: _____ (in module plane)
 Measure temp & irradiance at the same time as reading inverter outputs

	Location and quantity	Model number
AC disconnect		
DC disconnect		

Inverter 1 PV String Measurements

	Number of modules	V _{OC}	I _{mp}
String 1			
String 2			
String 3			
Continue on additional sheet if necessary			

Inverter 2 PV String Measurements

	Number of modules	V _{OC}	I _{mp}
String 1			
String 2			
String 3			
Continue on additional sheet if necessary			

Notes:

Figure 5: Example commissioning checklist

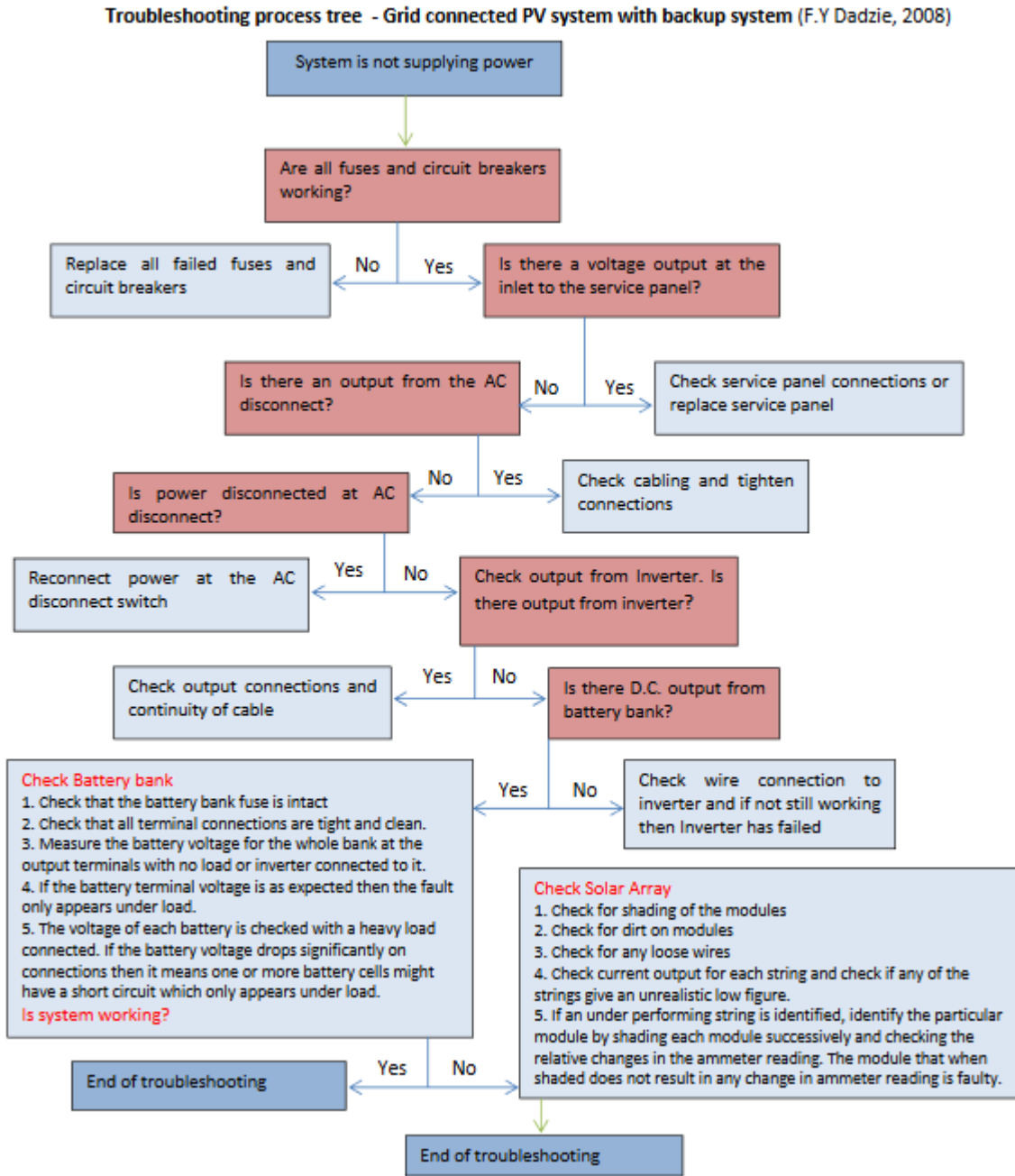


Figure 6: Example of a troubleshooting tree

Self-Check - 5	Written Test
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Instruction: Follow the below selected instruction

Answer all the questions listed below.

N°	Questions and answers
1	Why is it important to get as much detail as possible from the client? (2)
2	Why is a visual inspection required? (2)

Note: the satisfactory rating is as followed

Satisfactory	3 points
Unsatisfactory	Below 3 points

Answer Sheet

Score = _____

Rating: _____

Name

Date

Information Sheet 6	Preparing tools and materials and checking against damage
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6 Preparing tools and materials and checking against damage

It is important to check all tools and materials before taking it to site. There is nothing worse than realising on site that the meter you have is not working or that the spare part is damaged!

6.1 Measuring equipment

Always make sure that any measuring equipment taken to site:

- Is operational by doing a test measurement;
- Have a fully charged battery or spare battery;
- That the charger is also taken to site;
- That the technician knows how to operate the equipment and interpret readings.

6.2 Spare Parts and Consumables

- Always make sure that spare parts are in working order.
- Spare parts may not always be new but can be repaired units from previous swap-outs.
- Ideally test all spare parts under load.
- Distilled water to fill batteries;
- Make sure you have the correct rating wire, connectors, switched and fuses suitable for the installation and that it is in good working order.
- Make sure you have all consumables like cable ties, isolation tape, labels, fixtures and fittings etc.

Self-Check - 6	Written Test
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Instruction: Follow the below selected instruction

Answer all the questions listed below

N°	Questions and answers
1	What is important to consider regarding test equipment taken to site? (3)

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = _____
Rating: _____

Name

Date

7 Preparing personal protective equipment (PPE)

7.1 Required PPE

The type of installation will dictate what protective equipment will be required:

- Ladders, scaffolding and safety harnesses may be required if the installation is on a high roof or structure
- Protective gloves, hard hats and non-slip shoes may also be required
- Where batteries are installed, always take appropriate PPE like gloves and safety glasses, specifically when filling the batteries
- Take the correct neutraliser to neutralise spilled battery acid e.g. sodium bicarbonate
- Protective gloves rated for working on live electricity may be required, specifically when working on critical sites which may not be switched off and when doing live measurements
- Lock-out devices to lock out circuits while working on it
- When working on live equipment, special protective glasses and gloves will be required

7.2 Training

It is also important that the technicians on site are trained to use the PPE correctly and safely. In many countries, it is compulsory to undergo certain safety training before working on site e.g. 'working at heights training'.



Figure 7: Working at heights (internet)

Self-Check - 7	Written Test
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Instruction: Follow the below selected instruction

Answer all the questions listed below.

N°	Questions and answers
1	Name 3 types of PPE to take to site (3)

Note: the satisfactory rating is as followed

Satisfactory	3 points
Unsatisfactory	Below 3 points

Answer Sheet

Score = _____
Rating: _____

Name

Date

8 Reading and interpreting work instructions

It is important that the technician reads and understands the work instructions, and knows how to interpret it.

Work Instructions provide step-by-step instructions to perform each task. Work Instruction Procedures (Figure 9) are the most detailed type of procedure. This procedure documents the step-by-step requirements of each process task and can be used in well-defined tasks.

When tasks are not necessarily well defined (as in many diagnose and repair tasks), work instructions can also be in the form of checklists, “cheat sheets,” flowcharts, or any other documents that convey the necessary instructions.

In the PV world, many equipment manufacturers have troubleshooting guides in their installation manuals. Go through the specific equipment manuals beforehand. Check special instructions and specifically follow the troubleshooting guide from the installation manuals (see Figure 8). The troubleshooting guide can give valuable information relating to the symptoms the customer reported and can even prevent visiting the site.

From the information captured in the previous sections, there should be a clear understanding of what to expect at site, what to take to site and what to do on site.








Display	Meaning	Cause / Remedy
 E02	Communication error with the internal storage (EEPROM).	Disconnect the load, solar modules and battery. Re-install the device. If the error recurs, then please contact your specialist dealer.
 E03	Communication error on the external Steca bus (6-pin edge connector).	Check the plug connection at the 6-pin edge connector, check the power supply and check for correct functioning of external expansions. If the error recurs, then please contact your specialist dealer.
 E04	Short circuit in external temperature sensor.	Check the contacts of the 2-pin edge connector and remove the short circuit. Check sensor.
 E05	Overtemperature. The controller has switched off the load due to internal overheating.	Allow the controller to cool down. Check for possible causes of overheating (mounting location, other heat sources). Possibly reduce the charging current or load current. Make sure the controller is adequately ventilated.
 E07	Battery voltage too low. Voltage < 10.5 V or < 21.0 V.	Check installation. Check the battery voltage and manually recharge the battery if necessary. Loads directly connected to the battery can cause deep discharge!
 E08	Battery voltage too high. Voltage > 15.5 V or > 31.0 V.	Check installation. Check the battery voltage and check any additional charging sources if present.
 E09	Excessive load current. The permissible load current of the controller was exceeded, causing the load output to be switched off.	Reduce the load current at the load output. The load may cause current peaks. Try reconnecting the load.

Figure 8: Extract from Steca CC manual

Company Name:	Document Owner:
Work Instruction #:	Version:

1 Work Instruction

1.1 Purpose

Describe the purpose of the [official name of Work Instruction] at the [name of location and/or business unit]. Include any relevant background information, such as Cautions, Warnings or other information that the reader must be aware of before reading this document.

Start with the following: 'The purpose of this document is to provide instructions for _____.'

1.2 Scope

Describe the scope of the Work Instruction as well as the target audience (i.e. those who will use these instructions). Help the reader understand where this Work Instruction fits into other activities, such as its role in the Procedures Manual or technical documents. Identify the area or process that this instruction applies to.

Item	Purpose

1.3 Pre-requisites

Describe any information that must be read or equipment that must be in place before starting the instructions, for example, tools, software, documents, and/or certifications.

Start entering your text here.

1.4 Responsibilities

Identify the personnel that have key roles in the Work Instruction and describe how their responsibilities relate to this activity. If necessary, include contact information.

Name	Role	Email

Company Name	Document Owner:	
Work Instruction	Version:	Date:

1.5 Criteria

Where appropriate, identify any technical or workmanship standards that are required to perform these instructions.

Criteria #	Purpose

1.6 Instructions

Provide the steps required to perform this Work Instruction.

List the steps to be taken to complete the scope of this work instruction in the correct sequence. You can describe the work instructions using flowcharts, bullet instructions, text, images, numbered instructions or any combination, providing the instructions are easily understood and accurate

Step #	Work Instruction # <WI_XXX_YYY>: Use an active verb phrase to describe this instruction												
1	Describe this step. Include screenshots and images where necessary.												
2	Describe this step.												
3	Describe this step.												
4	Describe this step.												
5	Describe this step.												
6	Use an If-Then table to describe steps where the user is presented with different options												
	<table border="1"> <thead> <tr> <th>If</th> <th>Then</th> <th>Else</th> </tr> </thead> <tbody> <tr> <td>User does this</td> <td>Follow this step</td> <td>Go to Step X</td> </tr> <tr> <td>User does this</td> <td>Follow this step</td> <td>Go to Step X</td> </tr> <tr> <td>User does this</td> <td>Follow this step</td> <td>Go to Step X</td> </tr> </tbody> </table>	If	Then	Else	User does this	Follow this step	Go to Step X	User does this	Follow this step	Go to Step X	User does this	Follow this step	Go to Step X
If	Then	Else											
User does this	Follow this step	Go to Step X											
User does this	Follow this step	Go to Step X											
User does this	Follow this step	Go to Step X											

Company Name:	Document Owner:
Work Instruction #:	Version:

Step #	Work Instruction # <WI_XXX_YYY>: Use an active verb phrase to describe this instruction
7	
8	
9	
10	

1.7 Revision History

Describe previous changes made to this document.

Revision	Description of Change	Effective Date
A		
B		
C		
D		
E		

1.8 References

List the name and reference numbers of any documents referenced in this Work Instruction. You must also reference procedures that control the Work Instruction including its control number. You may also include resources that may be useful when performing this procedure, such as for industry standards and links to other Procedure Manuals.

Doc #	Author	Document Title

Page 3 of 4
Document Name: Work Instruction Templates
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Figure 9: Work instruction example (<https://klariti.com/>)

Self-Check - 8	Written Test
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Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	Questions and answers
1	Troubleshooting guide from the installation manuals should only be consulted when all else fail?
	True or false:

Note: the satisfactory rating is as followed

Satisfactory	1 point
Unsatisfactory	Below 1 point

Answer Sheet

Score = _____

Rating: _____

Name _____

Date _____