

Short-Course

Solar PV System Installation and Maintenance

NTQF Level III

Learning Guide -21

| | |
|---------------------------|---|
| Unit of Competence | Diagnose, Repair and Maintain PV System |
| Module Title | Diagnose, Repair and Maintaining PV System |
| LG Code | EIS PIM3 M15 0120 LO3-LG21 |
| TTLM Code | EIS PIM3 TTLM 0120v1 |

LO 3: Repair or rectify the fault-21

Instruction Sheet**Learning Guide: - 21**

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

- Confirming required isolations with site requirements
- Undertaking appropriate repair procedures
- Replacing & repairing faulty, worn, damaged or unsecured components
- Selecting and replacing parts and components.
- Reconnecting the disconnected components for testing
- Checking all terminations are electrically and mechanically sound
- Repairing or rectifying all faults with the work plan.
- Performing and permitting final job inspection.

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: -

- Confirm required isolations with site requirements
- Undertake appropriate repair procedures
- Replace & repair faulty, worn, damaged or unsecured components
- Select and replacing parts and components.
- Reconnect the disconnected components for testing
- Check all terminations are electrically and mechanically sound
- Repair or rectifying all faults with the work plan.
- Perform and permit final job inspection.

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: 63), Sheet 2 (page: 66), Sheet 3 (page:69), Sheet 4 (page: 73), Sheet 5 (page: 75), Sheet 6 (page:77), Sheet 7 (page: 80), Sheet 8 (page: 82)
4. Accomplish the Self-Check 1 (page: 65), Self-Check 2 (page: 68), Self-Check 3 (page: 72), Self-Check 4 (page: 74), Self-Check 5 (page: 76), Self-Check 6 (page: 79), Self-Check 7 (page: 81), Self-Check 8 (page: 84)

LO3. Repair or rectify the fault

| | |
|---------------------|---|
| Information Sheet 1 | Confirming required isolations with site requirements |
|---------------------|---|

1 Confirming required isolations with site requirements

When repair done on a separate day, again undertake safety measures (disconnect etc., check LO2 Information Sheets 1 & 6).

1.1 Confirm Isolation Points

Make sure that the isolation points on site and on the drawings correspond. Identify all the points that need to be isolated.

- All fuses (on PV modules, Battery and inverter).
- All disconnect switches and circuit breakers.

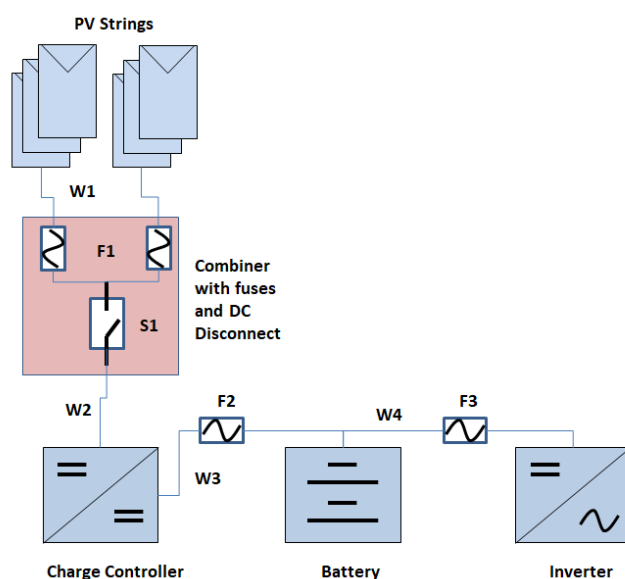


Figure 26 – Possible points for isolation

1.2 Notification

On site, notify the people on site that you will be working on the system. This will allow them to finish critical jobs and prevent them from switching on devices that you may have switched off.

1.3 Isolate

One of the design considerations for electrical safety is to isolate the circuit. The use of isolation equipment to support preventive maintenance and repair for proper

implementation of lockout/tag-out procedures is an essential provision for electrical safety.

Lockout devices are designed to keep energy-isolating devices in a safe or "off" position, preventing machines or equipment from becoming energized. These devices can't be removed without a key or other verified unlocking mechanism or through extraordinary force by using bolt cutters or a similar tool.

Tagout devices are warning tags attached to energy-isolating devices to warn employees not to turn on or re-energize the machine. Tagout devices are easier to remove and provide less protection. It's best practice to use the two together.



Always make sure that these measurements are taken with the correct safety procedures and PPE.

It is important to disconnect and isolate the components for some measurements like checking the cables for insulation faults etc. The following needs to be considered:

- Never disconnect PV Modules when it is under load. Always disconnect the modules at the isolator switch.
- Remember that even if a PV module is disconnected, it will still produce a voltage.
- Make sure that lock-out procedures are followed to prevent someone from switching on the circuit while you are measuring.
- Before a wire is touched, always measure first to confirm that it is not live.

| | |
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| Self-Check - 1 | Written Test |
|-----------------------|---------------------|

Instruction: Follow the below selected instruction

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

| N° | Questions and answers |
|----------|--|
| 1 | Before switching of circuits, people should be notified for them to switch off computers etc. |
| | True or false: |
| 2 | Always disconnect the modules at the isolator switch. |
| | True or false: |
| 3 | Before a wire is touched, always measure first to confirm that it is not live. |
| | True or false: |

Note: the satisfactory rating is as followed

| | |
|----------------|----------------|
| Satisfactory | 3 points |
| Unsatisfactory | Below 2 points |

Answer Sheet

Score = _____

Rating: _____

Name

Date

2 Undertaking appropriate repair procedures

The repairs that need to be undertaken will depend on what is wrong with the system and what needs to be repaired. LO2 deals with diagnosing the problem.

2.1 Wrong use of the system

If the user is using the system incorrectly, there are two courses of action:

- Educate the user about the proper use of the system.
- Modify the system for the user to be able to use it in the way that he wants to (e.g. add more batteries, bigger inverter etc. if he needs a higher load than what the system was designed for).

2.2 Warranty Claims

Always make sure if equipment that needs replacing are still under warranty. Follow the supplier's process to get the equipment repaired or replaced.

When you contact the supplier, have the following information ready:

- Serial number of the product.
- Where and when did you purchase?
- What are the other system components?
- What have you already tried?
- Pictures of the installation.
- Describe the exact steps to re-create the problem and the behaviour you are seeing.

2.3 Replace with new component

When replacing with a new component, either select the same or if not available matching component, with the same or similar specifications. If a similar specification component is unavailable, the system design should be reviewed to confirm if the replacement component will work or if other changes need to be done.

2.4 Customer Interaction

Always keep the customer informed of the status. Discuss with the customer whether the repair falls under the system warranty or if and what costs will be involved before repairing.

2.5 System Problems

Problems can be divided into the following categories:

- PV modules

- DC Cabling
- Connectors and junctions
- Switches and Fuses
- Charge Controller
- Batteries
- Inverter
- AC Circuits
- Appliances

| | |
|-----------------------|---------------------|
| Self-Check - 1 | Written Test |
|-----------------------|---------------------|

Instruction: Follow the below selected instruction

Answer all the questions listed below.

| N° | Questions and answers |
|----|--|
| 1 | Name 5 main areas of problems with PV Systems (5) |
| | |

Note: the satisfactory rating is as followed

| | |
|----------------|----------------|
| Satisfactory | 4 points |
| Unsatisfactory | Below 3 points |

Answer Sheet

Score = _____

Rating: _____

Name

Date

| | |
|----------------------------|--|
| Information Sheet 3 | Replacing & repairing faulty, worn, damaged or unsecured components |
|----------------------------|--|

3 Replacing & repairing faulty, worn, damaged or unsecured components

Replacement or repairing of faulty equipment will depend on the type of equipment and type of problem encountered.

3.1 System Problems Areas

Problems can be divided into the following categories:

- PV modules
- DC Cabling
- Connectors and junctions
- Switches and Fuses
- Charge Controller
- Batteries
- Inverter
- AC Circuits
- Appliances

3.1.1 PV Modules

If PV modules need to be replaced, always follow the correct isolation procedure. Never disconnect PV modules under load. Always isolate the circuit before disconnecting a PV module. PV Modules can still produce power, therefore care needs to be taken that there are no open wires.

Remove the faulty module(s) and replace. It may be that the exact same module cannot be found anymore. In that case, a module with similar size and characteristics should be sourced. If it is not possible, a whole string may need to be replaced. Remember that in a serial connection the weakest component in a string determines the performance of the whole string. As a consequence, a broken module should not be replaced with a module with a lower power rating.

In practice, replacing a failed panel on an old system can get tricky because it may be difficult to find a panel with the right specifications. Modern panels may be 300 watts or more, compared to 150 to 250 watts for old panels. The new panel may need to have the same number of cells, depending on how the array is configured, and will most likely need to have the same physical dimensions so it will fit in the array.

3.1.2 DC Cabling

DC cables that are damaged or cracked should be replaced with PV rated cable and not just repaired with isolation tape etc. Isolate the string and replace the cable by first

putting the connectors on at both sides before connecting to the array so that there are no exposed ends that can be live.

3.1.3 Connectors and junctions

Similar to cables, connectors and junctions that are damaged should be replaced. Make sure that connectors are not put on cables that are live; first isolate.

3.1.4 Switches and Fuses

Switches and fuses that are damaged or blown should be replaced with the same rating replacements. NEVER replace fuses with pieces of wire, metal etc. Switches and circuit breakers should also be of the same rating.

If fuses blow constantly or circuit breakers trip continuously, review the design to make sure that the sizes are appropriate.



Figure 27: Wrong fuse 'replacement'

3.1.5 Charge Controller

Follow the supplier's instructions. In general, isolate the PV inputs first, then isolate the batteries. Replace the Charge Controller but make sure that the correct settings (e.g. DIP switches) are set as per the original. Connect the Batteries before connecting the PV Modules.

3.1.6 Batteries

When the batteries need to be replaced, the charge controller and inverter need to be isolated from the batteries. Start by isolating the PV side from the charge controller,

isolate the loads from the inverter, then isolate the battery. When replacing with a different battery (specifically Lithium), make sure that the Charge Controller is compatible with the battery and that the Voltages are the same.

3.1.7 Inverter

Replace the inverter by isolating the loads first, and then isolate the inverter from the batteries. Replace the inverter (make sure that all settings are similar to the original), connect it to the batteries and connect the AC loads.

3.1.8 AC Circuits

Work on the AC circuit should be done by a qualified electrician according to the electrical regulations for the country.

3.1.9 Appliances

If appliances are faulty, replace with similar rating appliances. Be careful of appliances with much higher ratings as the original as it can drain the battery quicker or overload the inverter.

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| Self-Check – 3 | Written Test |
|-----------------------|---------------------|

Instruction: Follow the below selected instruction

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

| N° | Questions and answers |
|-----------|--|
| 1 | Damaged DC cables can be repaired with insulation tape. |
| | True or false: |
| 2 | When you don't have a fuse, a thin piece of wire can be used. |
| | True or false: |
| 3 | When you don't have a fuse, a thin piece of wire can be used. |
| | True or false: |

Note: the satisfactory rating is as followed

| | |
|----------------|----------------|
| Satisfactory | 3 points |
| Unsatisfactory | Below 3 points |

Answer Sheet

Score = _____

Rating: _____

Name

Date

4 Selecting and replacing parts and components

When selecting replacement parts, the following needs to be considered:

- The size of the replacement part.
- The electrical characteristics.
- The influence on the rest of the system.

4.1 Size of replacement part

It is quite important to consider the physical size of the replacement part to see if it will fit in the original area. This is specifically true for PV modules that need to fit onto a frame with other modules.

4.2 The Electrical characteristics

The electrical characteristics of the replacement part needs to be similar to the original. This includes:

- PV module no of cells (voltage) for parallel connected systems
- PV module current
- Battery voltage
- Battery rating (Ah)
- Charge Controller input voltage
- Charge Controller input current
- Charge Controller output voltage
- Inverter input voltage
- Inverter output power rating
- Cables, fuses and circuit breaker current and voltage ratings

4.3 The influence on the rest of the system

The replacement part's influence on the rest of the system needs to be considered when it cannot be replaced with the same as original. Always make sure:

- That it will fit without contravening ventilation spaces etc.
- That the electrical ratings are the same e.g. same voltage
- That the cable connectors are the same else these will have to be replaced as well
- That the system documentation is updated

| | |
|----------------|--------------|
| Self-Check - 4 | Written Test |
|----------------|--------------|

Instruction: Follow the below selected instruction

Answer all the questions listed below

| N° | Questions and answers |
|----|---|
| 1 | Name 5 electrical characteristics that need to be considered when replacing components: (5) |
| | |

Note: the satisfactory rating is as followed

| | |
|----------------|----------------|
| Satisfactory | 4 points |
| Unsatisfactory | Below 4 points |

Answer Sheet

Score = _____

Rating: _____

Name

Date

Information Sheet 5

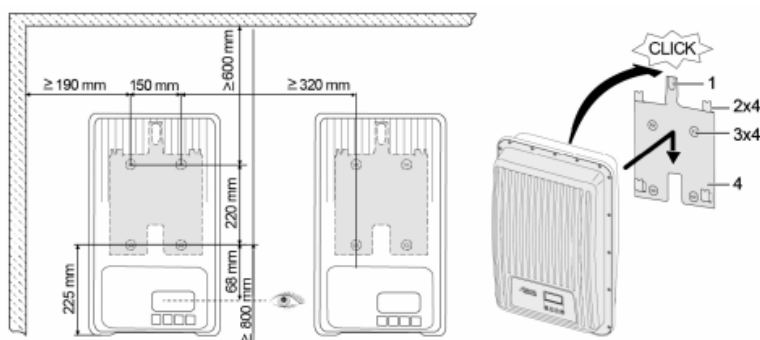
Reconnecting the disconnected components for testing

5 Reconnecting the disconnected components for testing

When installing the replacement part, it is important to:

- Follow safety instructions and wear appropriate PPE
- Install it according to the manufacturer's instructions
- Make sure that all settings are set correctly
- To commission it according to manufacturer's instructions e.g. start-up in the correct sequence etc.
- If applicable, test communication to the device
- To test it properly with the rest of the system.

5.2 Mounting the inverter



1. Fasten the mounting plate (4) to the mounting surface with 4 screws (3). The locking plate (1) points upwards.
2. Place inverter on the mounting plate.
3. Hook the 4 locating pins on the back of the inverter into the retaining tabs (2) of the mounting plate.
4. Press inverter against the mounting plate. The detent on the back of the inverter engages audibly in the locking plate (1).

5.3 Preparing AC connection



DANGER

Voltage

There is a risk of death by electrocution.

- ▶ Follow the safety instructions and warning notices in chapter 5.1.
- ▶ Never disconnect nor connect the plug connection while the AC connection is live.
- ▶ Install the circuit breaker prior to any work on the AC connection.

Figure 28: Extract from installation instructions

| | |
|-----------------------|---------------------|
| Self-Check - 5 | Written Test |
|-----------------------|---------------------|

Instruction: Follow the below selected instruction

For each of the following question choose the best answer and circle the letter of your choice.

| N° | Questions and answers | |
|----------|---|---|
| 1 | When installing the replacement part, it is NOT important to: | |
| | A – Follow safety instructions and wear appropriate PPE | B – Make sure that all settings are set correctly |
| | C – Make sure that it is the same colour | D – To test it properly with the rest of the system |

Note: the satisfactory rating is as followed

| | |
|----------------|---------------|
| Satisfactory | 1 point |
| Unsatisfactory | Below 1 point |

Answer Sheet

| |
|---------------|
| Score = _____ |
| Rating: _____ |

Name

Date

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| Information Sheet 6 | Checking all terminations are electrically and mechanically sound |
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6 Checking all terminations are electrically and mechanically sound

A PV system electrical fault often results from improper wiring. Specifically, points of connection, tension and friction are particularly notorious for being a fault source. Proper re-installation mitigates the risk of serial and parallel arcs, short-circuits and ground faults along the entire PV circuit.

The following paragraphs were adapted from (SPW, 2018)

6.1 PV Circuits

Conductor joints should occur in a transition box, enclosure or a connection device approved for the wire type and environment. Connections must be solid to avoid risk to performance and property.

Modular connectors such as MC4 for PV circuits are easy and fast if done properly. PV circuits can be extended and/or combined with manufactured extension cables, but if making your own, use OEM connection parts and approved crimping tools, methods.

Keep PV source circuit wires from dangling by using wire clips. This not only looks nicer but eliminates ground fault and shock risk due to wire abrasion. It also hides the wire from sharp-toothed rodents looking for something to chew. If using metallic zip ties, be careful not to over-tighten and risk insulation damage. Likewise, don't over-bend the wiring in an attempt to make a tight coil.

6.2 Other Circuits

Loose connections risk serial arcs. Make sure to have properly rated connectors to avoid risking parallel arcs.

For pass-through and combiner transition boxes that provide conductor connection points (terminals), the ones that are spring loaded are easiest. With screw-type compression terminals, use a torque driver and follow manufacturer's instructions on how tight to fasten them. Under-torqueing risks eventual loosening from thermal cycling and vibrations. Again, loose connection risk is easy to avoid. Over-torqueing risks the splaying of wire connector and potential cracking of termination housing.

6.3 Combiner box

Combiner boxes should include wire glands and rain-tight conduit connectors to prevent water intrusion (i.e., short circuits). The wire glands also provide strain-relief for connections inside to avoid serial arcs and ground faults.

6.4 Charge Controller/Inverter

Read installation instructions before first-time installation. Terminal connection types differ. Keep the following in mind:

- Verify wire sizes allowed; don't double-lug if not permitted.
- Strip the insulation per manufacturer's guide.
- Don't combine any aluminium to copper.
- Note torque specifications and use a calibrated torque driver.
- Tighten all loose screws even if no conductor is connected.
- Provide a service loop that doesn't exceed minimum bending radius.
- Tie down all loose wires so they don't interfere with closing the lid on the wiring area.
- The fewer the number of connections, the better.



Figure 29: Wire clips

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

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

| N° | Questions and answers |
|----------|--|
| 1 | When there is a loose wire, it can start arching and cause fires. |
| | True or false: |
| 2 | Wire insulation should be stripped per manufacturer’s guide. |
| | True or false: |
| 3 | Aluminium and copper can be combined as long as the wires are not too thin. |
| | |

Note: the satisfactory rating is as followed

| | |
|----------------|----------------|
| Satisfactory | 3 points |
| Unsatisfactory | Below 3 points |

Answer Sheet

| |
|---------------|
| Score = _____ |
| Rating: _____ |

Name

Date

7 Repairing or rectifying all faults with the work plan

The initial work plan will dictate all work that needs to be performed.

- It is important to refer back to the work plan and tick off all completed work to ensure not missing anything.
- Double check if all steps have been done and all errors fixed.
- Make sure that all part of the system works properly, not only the fixed part.
- Make sure that the description of the work is filled in completely and that any deviations, modifications or alterations (including new serial numbers) are duly noted.

| | |
|----------------|--------------|
| Self-Check - 7 | Written Test |
|----------------|--------------|

Instruction: Follow the below selected instruction

Answer all the questions listed below.

| N° | Questions and answers |
|----|---|
| 1 | Why is it important to follow the work plan? (3) |
| | |

Note: the satisfactory rating is as followed

| | |
|----------------|----------------|
| Satisfactory | 2 points |
| Unsatisfactory | Below 2 points |

Answer Sheet

| |
|---------------|
| Score = _____ |
| Rating: _____ |

Name

Date

8 Performing and permitting final job inspection

The following paragraphs were adapted from (Mayfield, 2010)

8.1 Introduction

After you visually check and confirm the installed equipment, you're ready to make the final electrical connections and check the system's operation. To do so, you must make electrical measurements before and after the disconnect devices are turned on. The Inspection check list is an important tool to provide an organised and systematic process:

- Verification of appropriate equipment listing and labelling, intended for the conditions of use, and installed in accordance with instructions.
- Verification of appropriate sizes and ratings for major components and balance-of-systems equipment.
- Verification of proper grounding.
- Verification that all equipment and the overall installation is completed in a workmanlike manner in compliance with all applicable codes.

Electrical testing includes the following measurements and verifications. Such test should be done by qualified person with electrical knowledge.

- Test AC circuits for continuity, Phasing, Voltage.
- Test DC circuits for continuity of grounding conductors.
- Verify correct DC polarity.
- Test String open-circuit voltage and short circuit current.
- Verify system functionality.
- Insulation resistance testing of PV arrays source and output circuits.

Always try to commission a system on a nice, sunny day when you have plenty of time to run the tests. By turning the system on in good weather, you can test the system when it's operating close to its maximum values. Take your time. Rushing this process to save 30 minutes isn't going to do anybody any good in the long run.

Be sure to record all the data you collect so you have an accurate record of the system's status on day one. You can create a checklist similar to **Error! Reference source not found.** that you can use on all of your installations. This form gives you places to record important system information, such as the array specification, voltage, and inverter power output values. By using the same form each time, you ensure that the proper checks are made (so you can sign off on the system) and documented for future reference (so you have an official record of the system's status). This information will serve as your base of reference if you're ever called in to troubleshoot any issues in the future.



Figure 30: Visual inspection (<https://everbluetraining.com/>)

8.2 Before final inspection

Particularly make sure that:

- All connections and terminations are tight and secure
- All cables are properly supported
- All labelling and cable marking has been done
- All cover plates are in place
- All waste has been cleared
- All documentation has been updated to as-is.
- Unusable equipment will be disposed of properly according to manufacturer's instructions.

11 Disposal



- ▶ Do not dispose of the inverter with household waste.
- ▶ Return the inverter to Steca customer service with the note: "For disposal".
- ▶ The device packaging consists of recyclable materials.

Figure 31: Disposal instructions

What to do with replaced parts? Dispose of in an appropriate way or recycle.

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

Answer all the questions listed below.

| N° | Questions and answers |
|----|---|
| 1 | Name 4 things to check in the final job inspection (4) |
| | |

Note: the satisfactory rating is as followed

| | |
|----------------|----------------|
| Satisfactory | 3 points |
| Unsatisfactory | Below 3 points |

Answer Sheet

| |
|---------------|
| Score = _____ |
| Rating: _____ |

Name _____

Date _____