ICLEI Local Governments for Sustainability

100% RENEWABLES CITIES & REGIONS ROADMAP

Supported by:

Federal Ministry for Economic Affairs and Climate Action

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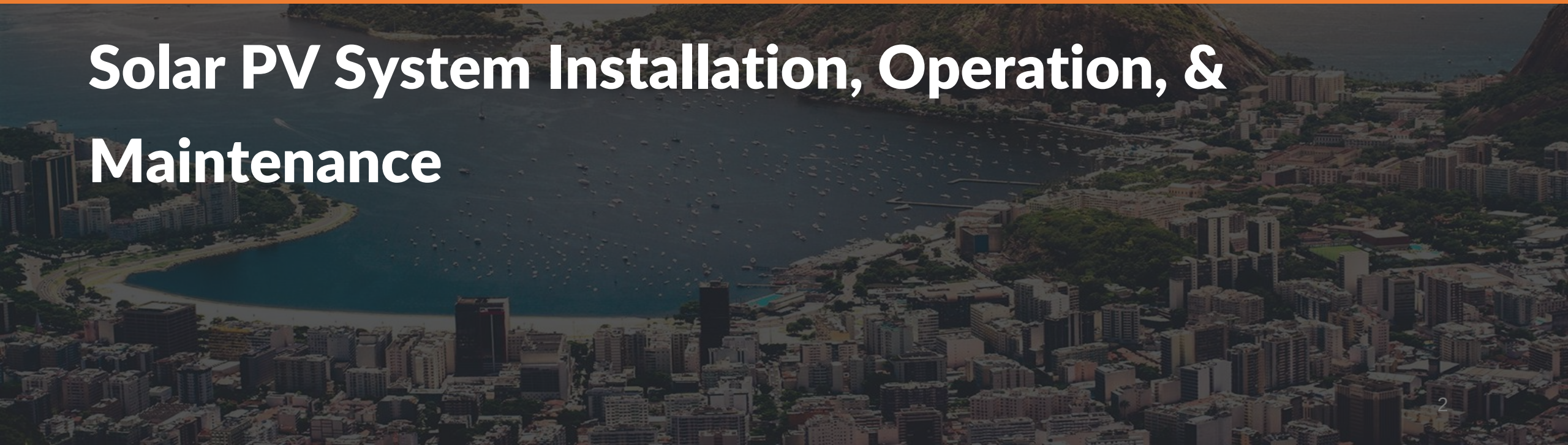
on the basis of a decision by the German Bundestag

Capacity Building Module: Solar Energy Basics & Solar Photovoltaic Systems

CHAPTER 6:

Solar PV System Installation, Operation, & Maintenance



CONTENTS

Occupational Safety and Health

Installation

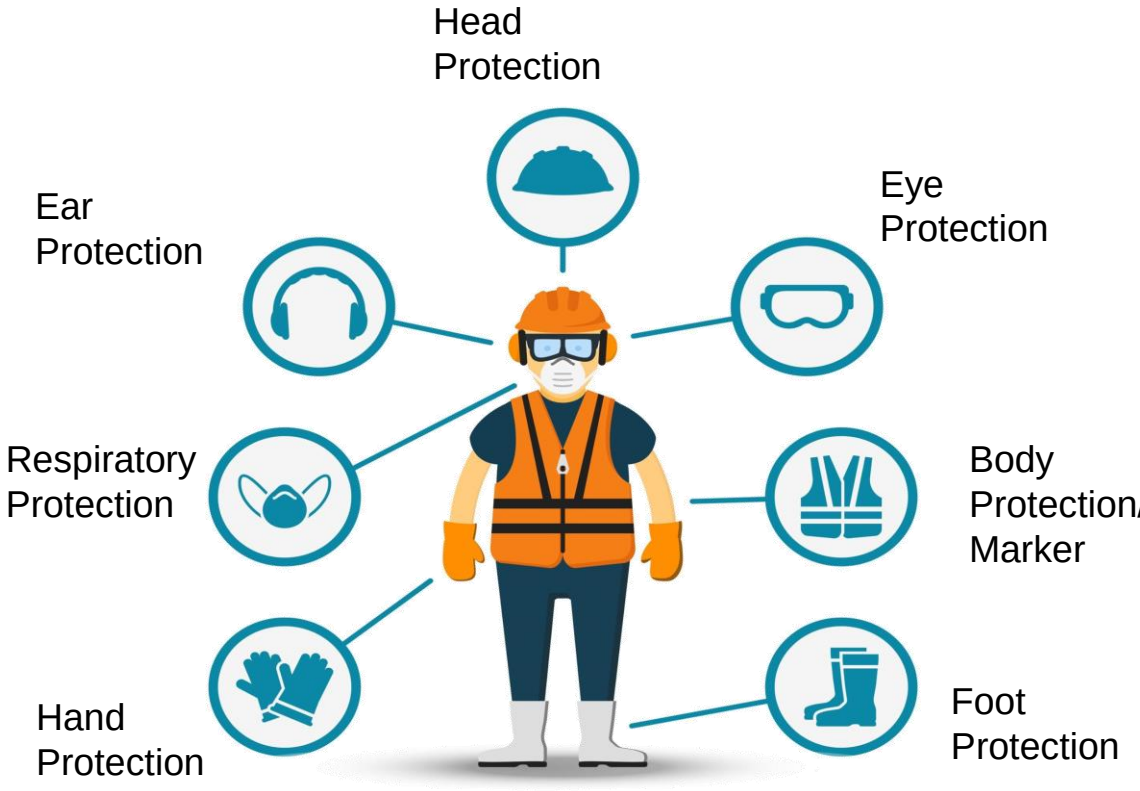
Operation and Maintenance

PART 1

OCCUPATIONAL SAFETY AND HEALTH

OCCUPATIONAL SAFETY AND HEALTH

Occupational Safety and Health is defined as all activities to ensure and protect the safety and health of workers through efforts to prevent occupational accidents and occupational diseases.



Personal Protective Equipment

PPE Body Harness for working at Heights

OCCUPATIONAL SAFETY AND HEALTH

Hazard	Objects / materials / actions that have the potential to cause accidents (accidents have not yet occurred). Example: tall trees in the solar PV area (could potentially fall or be struck by lightning).
Risk	The potential **loss** that can result from a hazard. Example: If a tree falls, it could fall on the solar power plant operator/installation.
Accident	An event **(already happened)** that is unintended (unintentional) and **causes casualties** (workers/materials). Example: a tree fell on a solar panel.
Incident	Event (already happened) but **there are no victims** (workers/materials). Example: a tree in the solar PV area fell but did not hit the operator or the solar PV installation.

PART 2

INSTALLATION

STAGES OF ROOFTOP SOLAR PV INSTALLATION

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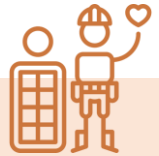
Pre-installation

Mechanical Installation

Support Structure | Solar Modules

Electrical Installation

Inverter | Wiring System | Grounding



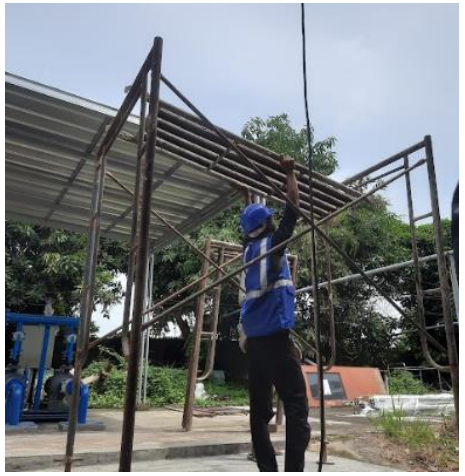
- Make sure to use the services of a certified technician.
- Completeness of supporting equipment and measuring instruments / muLtimeters, etc.
- Familiarity with instruction/user manuals and technical guides for all components.
- Construction services are familiar with work safety instructions.

PRE-INSTALLATION

Make sure your **Permit To Work** and **Job Safety Analysis** are in place!

ACCESS AND MOBILISATION PREPARATION

Ensure the required tools and measuring instruments are available for scaffolding (temporary structures that support the mobilisation of tools and equipment) and understood how to use them.

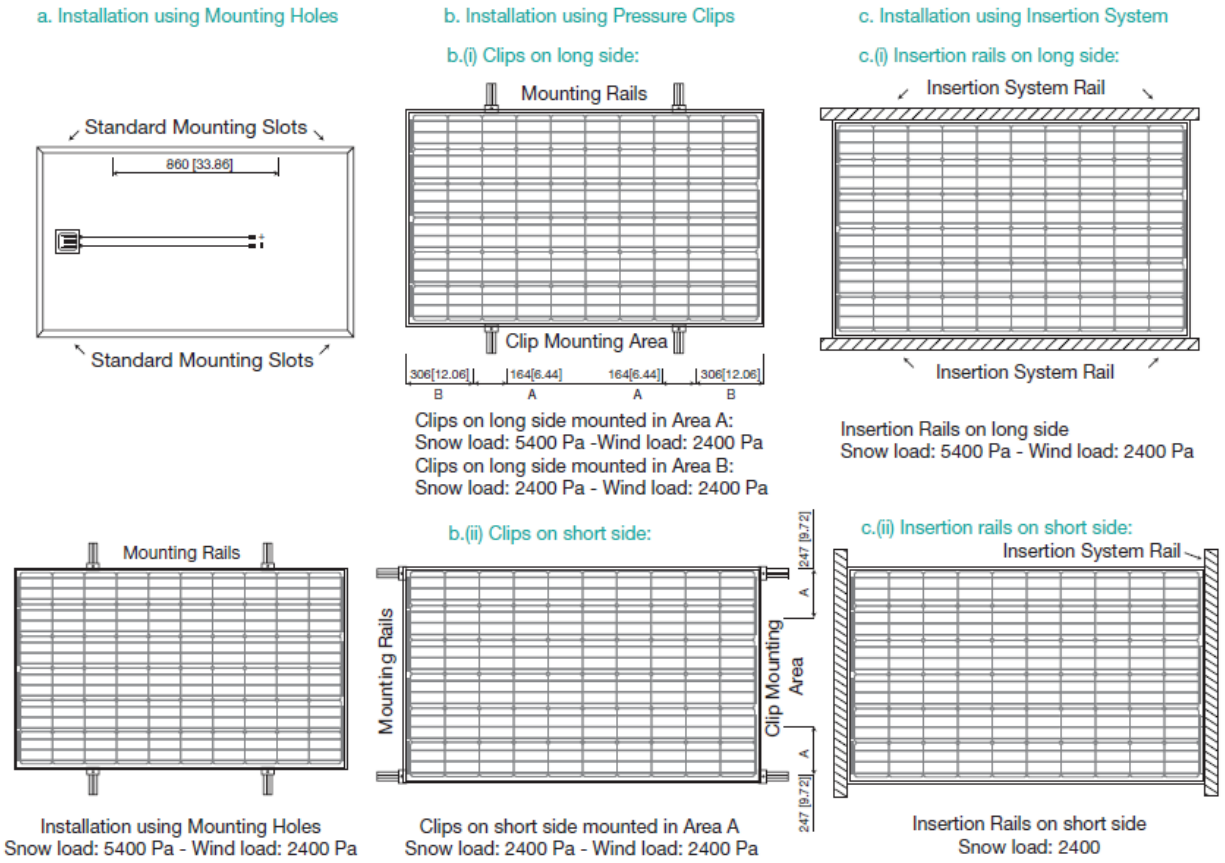


SOLAR MODULE MOBILISATION

Be sure to **read the User Manual** before installing!

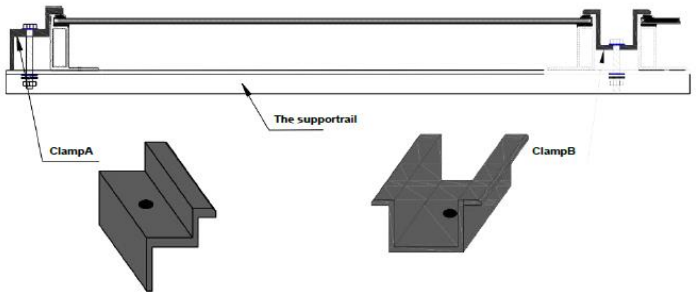
INSTALLATION OF PV MODULE SUPPORT STRUCTURE

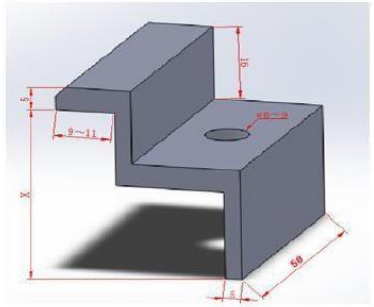
The installation of PV modules **must be in accordance with the technical guidelines** from the manufacturer, as it will affect the position and energy generated.

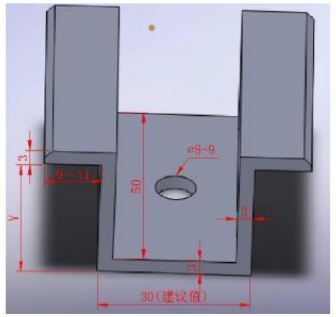


INSTALLATION OF PV MODULE SUPPORT STRUCTURE

Support rails and other necessary materials (such as screws) should be made of durable and corrosion-resistant, anti-rust and UV-resistant materials.



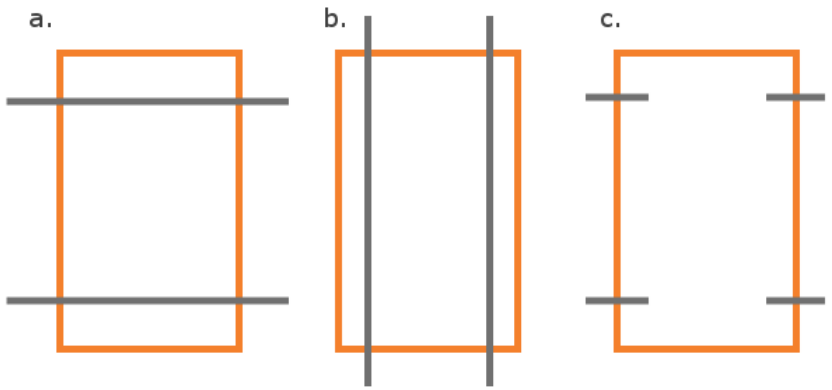




Fixture A: Fixture for edge module
For the 35*35 frame, the recommended value of X is34mm For the 40*35 frame, the recommended value of X is39mm

Fixture B: Fixture for inter mediate modules
For the 35*35 frame, the recommended value of X is25mm For the 40*35 frame, the recommended value of X is30mm

INSTALLATION OF PV MODULE SUPPORT STRUCTURE



INSTALLATION OF PV MODULE SUPPORT STRUCTURE

INSTALLATION TIPS:

- Ensure the distance between the solar module and the roof to accommodate the cooling process of the module (minimum 10 cm).
- Use seals for metal roofs and avoid leaks if roof penetrations are made.
- Ensure minimum 50 cm access road for maintenance process.
- Starting from determining the panel bracket points.

INSTALLATION OF PV MODULE

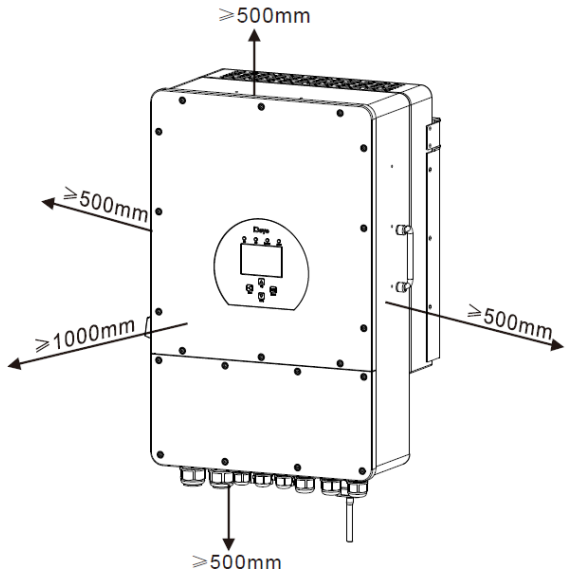
INSTALLATION TIPS:

- Do not use the solar module as a foothold.
- Always ensure the clamp is attached to the solar module.
- Solar module connectors are always under voltage when exposed to sunlight. Use PPE (Personal Protective Equipment) when connecting DC cables.

INVERTER INSTALLATION

INSTALLATION TIPS:

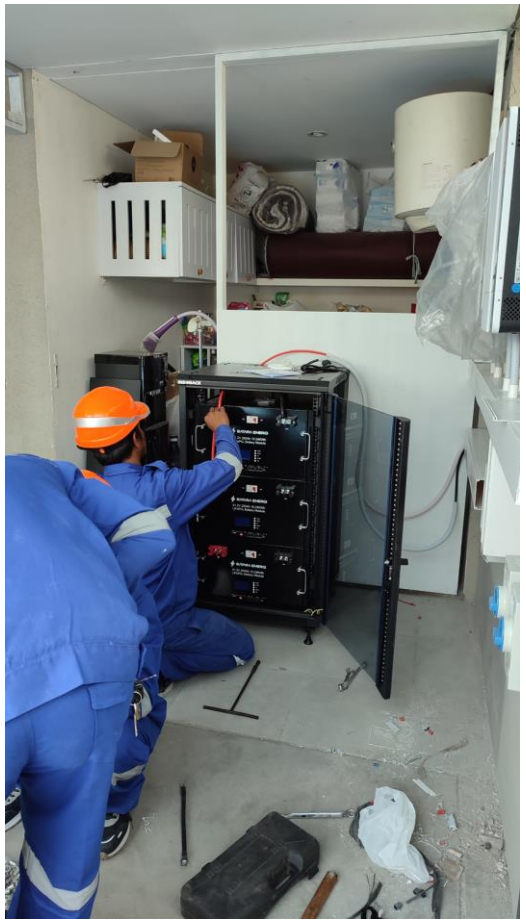
- Pay attention to the clearance area required for each type of inverter.
- Make sure the wall is made of concrete that can support the weight of the inverter. If not, choose a different type of inverter. Match the type of inverter to the strength of the wall.
- Always read the installation manual.
- Avoid direct exposure to sunlight on the inverter, overheating of the inverter may reduce power output.
- The inverter must be equipped with a protection system from lightning strikes at the input or output.
- Avoid too much distance between the inverter and solar modules. 1.5% maximum voltage drop.
- The inverter must be easily accessible.



BATTERY INSTALLATION

INSTALLATION TIPS:

- Use tools such as a hand stacker, trolley, or forklift.
- Use a closed rack if available.



BALANCE OF SYSTEM (BOS) INSTALLATION

INSTALLATION TIPS:

- Pay attention to the dimensions and weight of the electrical panel being used.
- Use appropriate mounting (wall-mounted or free-standing).
- Consider the cable bending radius and the space required.

DC CABLE INSTALLATION

Installation Tips

- Ensure sufficient DC cable length and provide 10-20% spare from design.
- Trim cables in the mounting rail or conduit using trays or cable ties.
- Avoid cable installations with a bending radius that is not in accordance with the cable requirements.
- Avoid installation of high-voltage DC cables inside buildings as much as possible. Use fire resistant materials for mechanical protection of DC cables.

DC CABLE INSTALLATION

Installation Tips

- Ensure that the maximum area of the cable inside the tray is not more than 60% of the tray or conduit area.
- No large holes or gaps for rodents to enter.
- Metal trays must always be connected to earthing.
- for mechanical protection of DC cables.

DC CABLE INSTALLATION

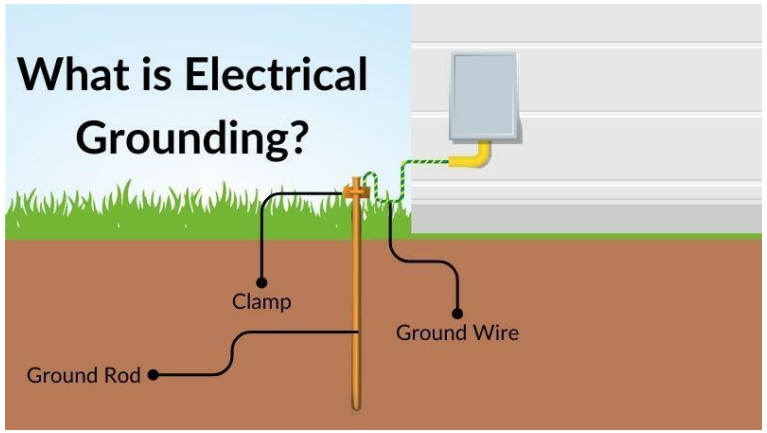
Installation Tips

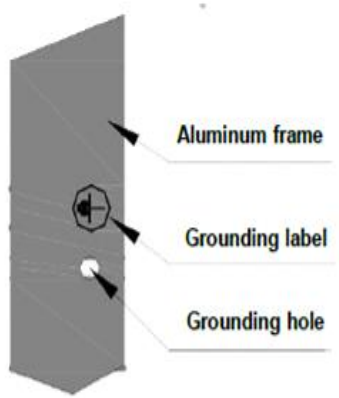
- Ensure proper cable connections at the MC4 connector.
- Cable ties should not be attached too tightly to the cable, to avoid the risk of fire and to facilitate future maintenance.
- Ensure safe cable routing. Improper cable routing may pose a safety risk due to high current flow. Sharp corners, sharp bends, or rough surfaces can damage the cable insulation, causing insulation errors and reducing protection of DC cables.

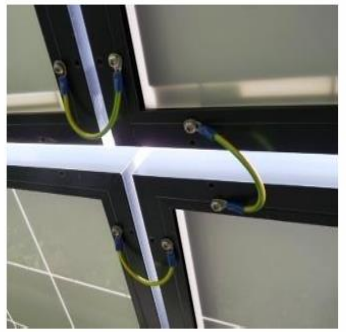
GROUNDING INSTALLATION

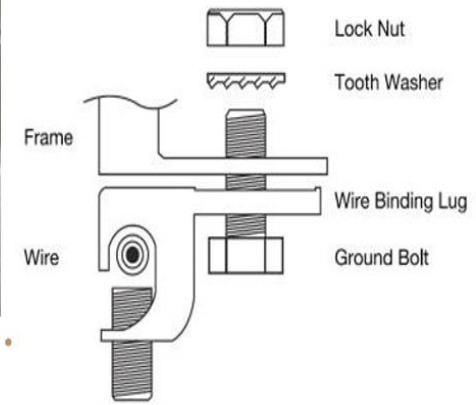
Installation Tips

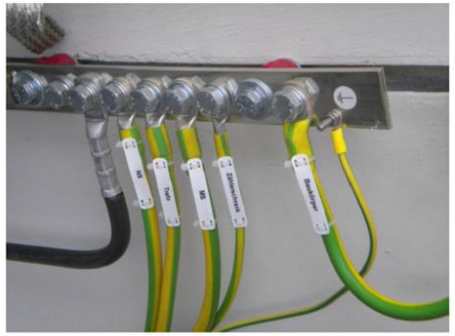
- Make sure all components are connected to the grounding system.





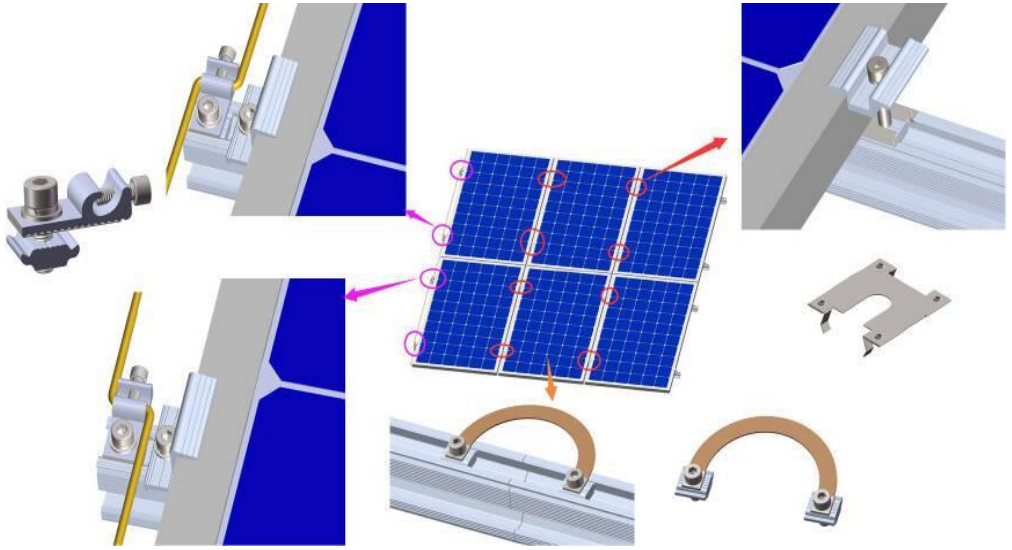






BONDING

Connecting exposed conductive parts that are not carrying electricity to the ground.



COMMISSIONING

Documentation and *Labelling*

- Completeness of documents, datasheets, technical drawings (single line diagrams), warranties, labels, danger signs

Visual inspection

- Component suitability
- Quality of installation and components
- Fire extinguishing system, *emergency exit*

Performance Verification

- Functional Solar PV
- Cable insulation
- IV curve solar module, thermograph

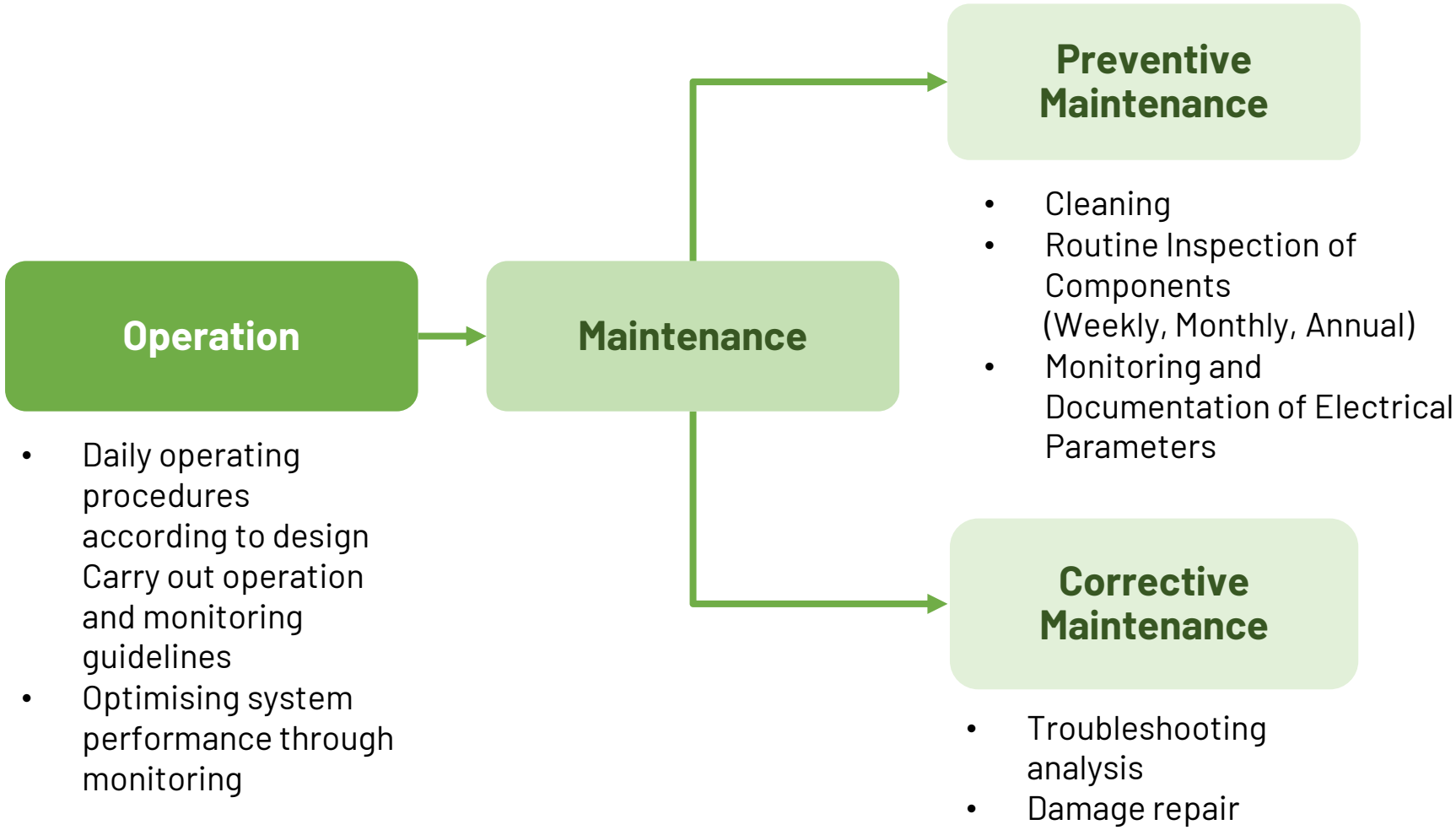
System test

- System reliability

PART 3

OPERATION AND MAINTENANCE

OPERATION AND MAINTENANCE



- Daily operating procedures according to design Carry out operation and monitoring guidelines
- Optimising system performance through monitoring

- Cleaning
- Routine Inspection of Components (Weekly, Monthly, Annual)
- Monitoring and Documentation of Electrical Parameters

- Troubleshooting analysis
- Damage repair

OPERATION AND MAINTENANCE

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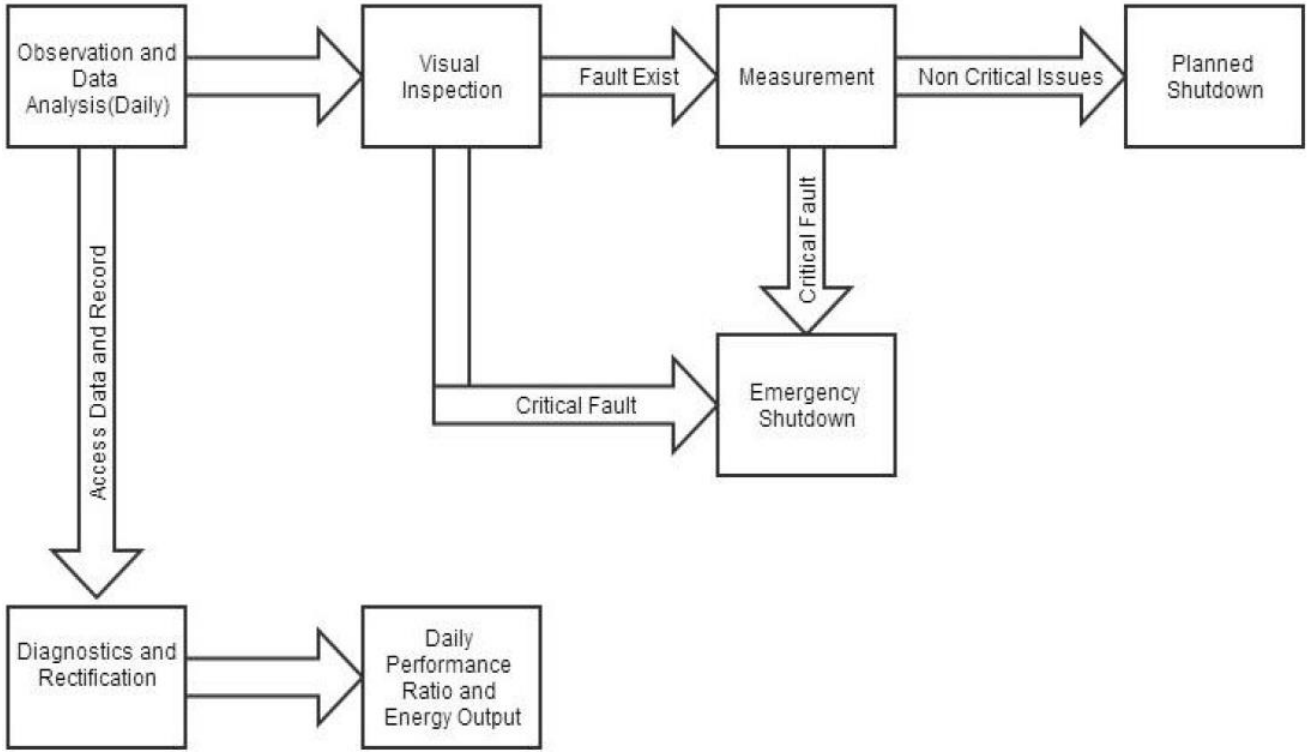
Objective:

- Ensuring the rooftop solar PV functions well in the long term.
- Ensuring the solar power system performs as expected.



KEY WORK INDICATORS

- Monitor rooftop solar PV operations and identify performance degradation and the need for maintenance/repairs.
- Evaluate and benchmark for further performance measurements and comparisons at the time of commissioning or re-commissioning
- Comparing the operation and performance of solar power plants in different geographical areas and designs and comparing designs with actuals.
- Detecting the performance degradation of solar power plants, investigating the problems and carrying out maintenance operations.

PERFORMANCE RATIO

Performance ratio, PR (%) is a **performance indicator of a solar power generation system which is the ratio between actual energy yield and reference yield**. PR can describe the overall losses in the solar power system when converting to electricity from solar modules to the AC interconnection point.

PR calculations can be done annually, monthly, or daily to determine the condition of the solar power plant.

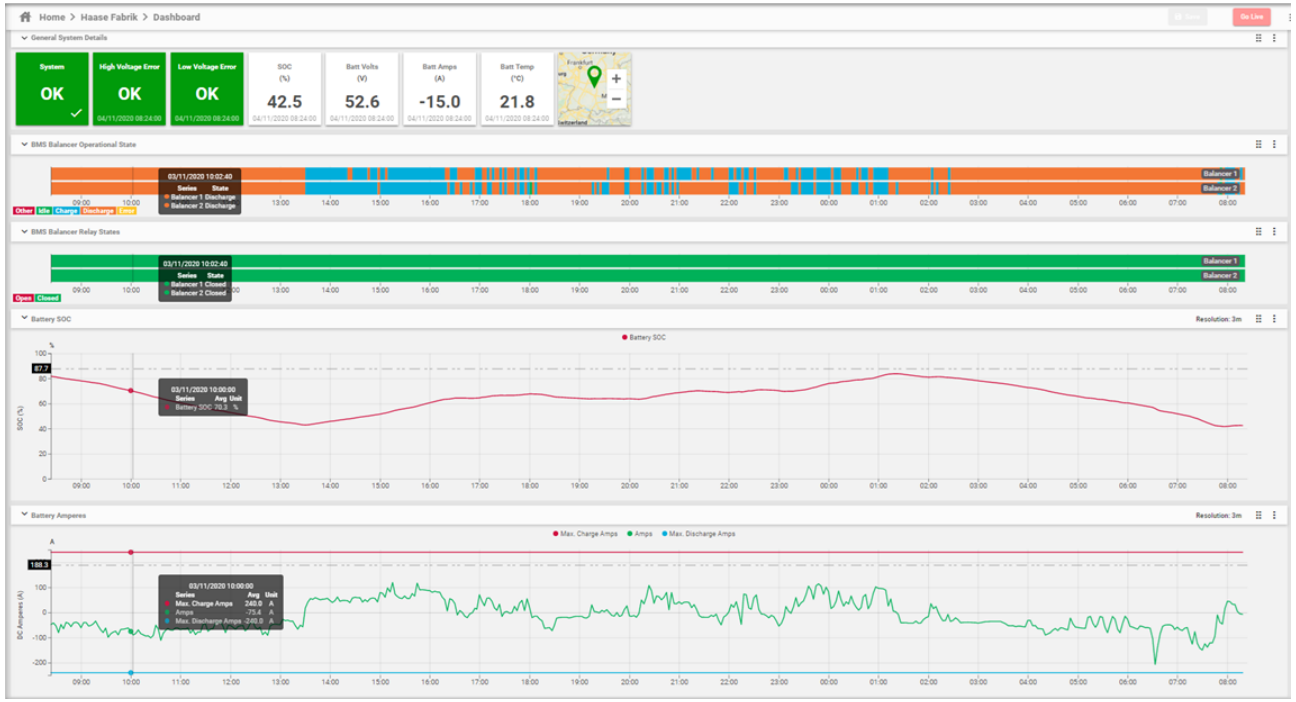
Performance ratio can depend on:

- Solar PV design (losses of inverters, cables, transformers, etc.)
- Solar module condition (cleanliness, shading, etc.), component degradation (i.e. solar module)
- Ambient/module temperature, inverter losses, transformer losses, availability (system downtime) and grid/load availability
- Energy not converted/used (off-grid) or curtailment

MONITORING SYSTEM

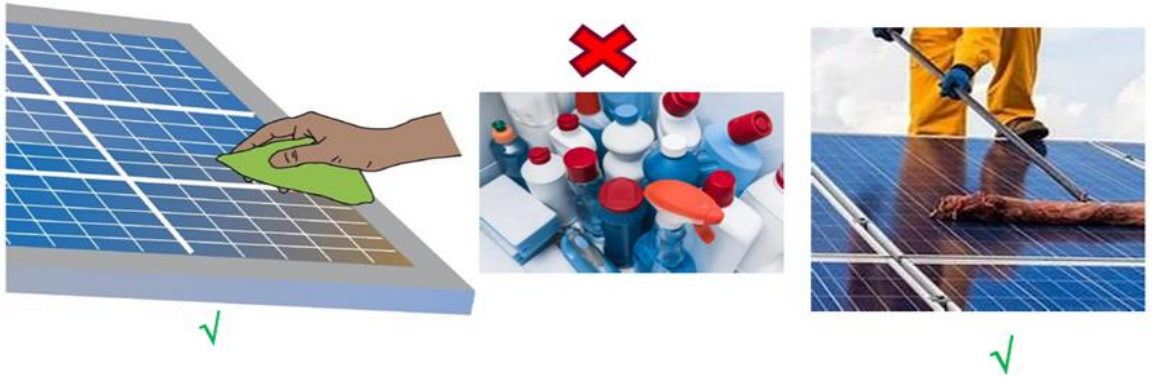
Benefits

- Monitoring of performance, status, and electrical energy production.
- Reduce preventive maintenance costs and assist in analysing/diagnosing when errors occur and providing solutions remotely.
- Increase system/component life and productivity.
- Estimated operational cost savings (monthly electricity bill).
- Evaluation material for optimisation of rooftop solar PV development in the future.



PREVENTIVE MAINTENANCE

- Solar module inspection (visual, IR, degradation).
- Mountings structure (bolts, rust, grounding, etc.).
- Cable (insulation).
- Inverter (fan, ventilation).
- Solar module glass cleaning.
- Measurement of grounding continuity and visual check of connectors.
- Cleaning of inverter components, combiner box from dust.
- Make sure the plant room is clean and not damp.



PREVENTIVE MAINTENANCE

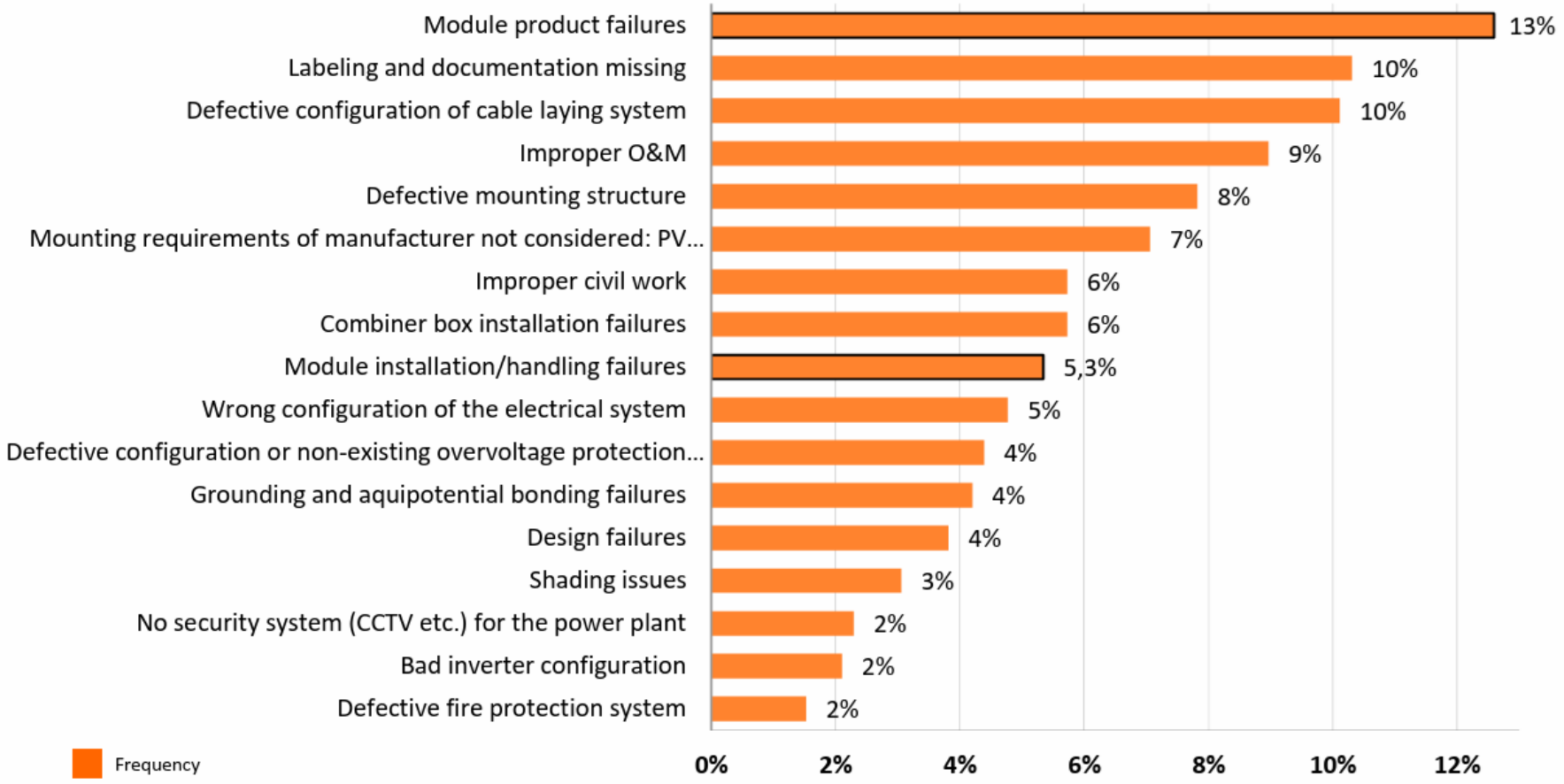
SUB-SYSTEM OR COMPONENT	MAINTENANCE ACTION	FREQUENCY	REMARKS	RESPONSIBLE
SITE	Verify: 1. General Cleanliness (accumulation of debris around and/or under array/ batteries and environment). Follow tips above. 2. Check impact of bats on the roof and PV system 3. Check shading of solar panels from surrounding trees. In case of shading, cut parts of tree that are causing shadow.	Weekly	Clean if necessary	In - Charges/volunteers
PV MODULES	1. Verify Cleanliness (accumulation of dust or fungus on array) 2. Cleaning: Simply wash with water to remove layers of dust and dirt. Follow tips above.	monthly	Clean if necessary	In- Charges/volunteers
	1. Visual check of connectors and cables 2. Check roof for cracks and holes and repair where necessary 3. Clearing of obstructions of sunlight/shading to	Quarterly	Repair/ tighten if necessary Trim trees if required.	In- Charges/volunteers
	Check for visual defects including: 1. Fractures 2. Cracks and Chips 3. Browning 4. Moisture Penetration 5. Frame Corrosion	Biannually	Modules with visualdefects should be further inspected for performance and safety to determine the need for replacement.	Technical focal persons
	Verify Bypass Diodes	Annually	Any defective seals, clamps and bypass diodes are to be replaced	Technical focal persons
	Verify Mechanical Integrity ofConduits	Quarterly	Any damaged conduit is to be replaced	Technical focal persons
	Verify Insulation Integrity of Cablesinstalled without conduit	Quarterly	Any damaged cableis to be replaced	Technical focal persons
WIRING INSTALLATION	Check Junction & Distribution Boxes for: 1. Tightness of Connections 2. Water accumulation/build up 3. Integrity of Lid Seals	Annually	Any defective seals,clamps, blocking diodes and surge arresters are to be replaced.	Technical focal persons
	4. Integrity of Cable Entrance and/or Conduit sealing 5. Integrity of Clamping devises			
ELECTRICAL CHARACTERISTIC	Measure Open Circuit Voltages	Annually		Technical focal persons
	Measure Short Circuit	Annually		

CORRECTIVE MAINTENANCE

- Diagnose errors or troubleshooting to identify the cause of the error.
- Minor reparation to restore the necessary function of the damaged item for a limited time until repairs are carried out.
- Repair to permanently restore necessary functions.
- Replacement of components with existing spare parts (minor reparation).

CORRECTIVE MAINTENANCE

The following graph shows the failures that often appear in rooftop solar PV operating systems:



Source: PI Berlin 2010-2016
63 TDD Projects in EU & Latin America (576 MWp)

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END OF CHAPTER 6 OF 7

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