

OPERATIONAL AND MAINTENANCE MANUAL

PV
Module



This manual is applicable to all PV module of Luxen Solar



Start for you



1. Introduction

1.1 Purpose01

1.2 Significance of O&M01

1.3 Scope of Application01

1.4 Basis of Compilation02

Disclaimer02

2. Requirements for O&M Personnel

2.1 Professional Skills03

2.2 Safety Awareness and Operating Standards04

3. PV Modules Inspection

3.1 PV Modules Introduction05

3.2 Regular Inspection07

3.3 PV Modules Inspection08

3.4 Electrical Safety Inspection09

3.5 Bracket and Grounding Inspection10

4. Cleaning and Maintenance of PV Modules

4.1 Cleaning of PV Modules11

4.2 Cleaning Requirements12

5. Troubleshooting and Emergency Plans

5.1 Common Failures15

5.2 Emergency Plans16

6. Records and Document Management

6.1 O&M Records17

6.2 Data Analysis18

6.3 Document Management18

7. Safety Precautions

7.1 Work Safety19

7.2 Electrical Safety20

7.3 Environment Safety20

8. Supplementary

Manual Review and Update21

01

Introduction

1.1 Purpose

This manual is intended to provide comprehensive and standardized guidance on the O&M of PV modules for power plant operators and maintenance personnel, ensuring safe, stable, and efficient operation of the modules, maximizing power generation efficiency, extending module service life, and providing a technical basis for the continuous optimization of the power plant.

1.2 Significance of O&M

PV modules are the core power generation equipment in a power plant, responsible for converting sunlight directly into electricity. Their operating status is crucial to the overall power generation and profitability of the plant. Proper operation and maintenance can promptly identify potential problems and prevent them from occurring or escalating, thereby improving power generation efficiency and extending module life. For example, regular cleaning and weeding can reduce dirt accumulation and surface obstruction, preventing hot spot effects.

It is recommended to maintain detailed records after each O&M to provide data support for the long-term operation of the power plant.

1.3 Scope of Application

This manual is applicable to the daily and regular O&M, troubleshooting and safety management of PV modules in all grid-connected power plant that have been put into normal use.

It covers key contents such as daily inspection, cleaning, clearing of obstructions and handling of common problems of PV modules.



1.4 Basis of Compilation

This manual is compiled in accordance with current national and industry standards and specifications in China, including but not limited to:

GB 50797-2012 "Design Specifications for PV Power Plant"

GB/T 35694-2017 "Safety Regulations for PV Power Plant"

GB/T 32900-2016 "Technical Specifications for Relay Protection in PV Power Plant"

IEC 62446 "Grid-Connected PV Systems - Testing, Documentation, and Maintenance Requirements"

Disclaimer

The copyright of all contents in this manual belongs to Luxen Solar, which is the result of its long-term technical accumulation and experience. Luxen Solar reserves the right to update product information and manuals without notice. For the latest version, please visit Luxen Solar's official website at <https://luxensolar.com/>.

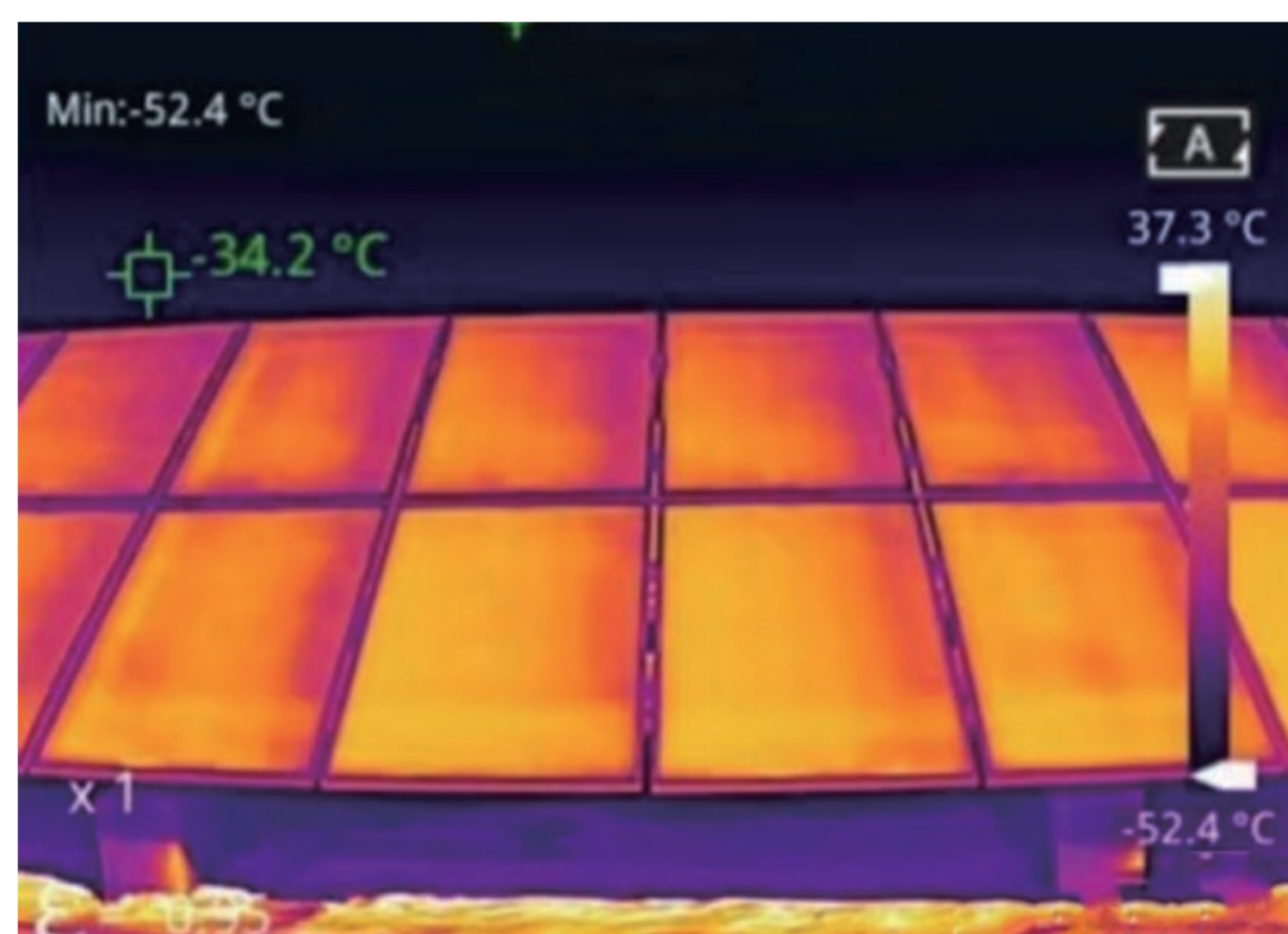
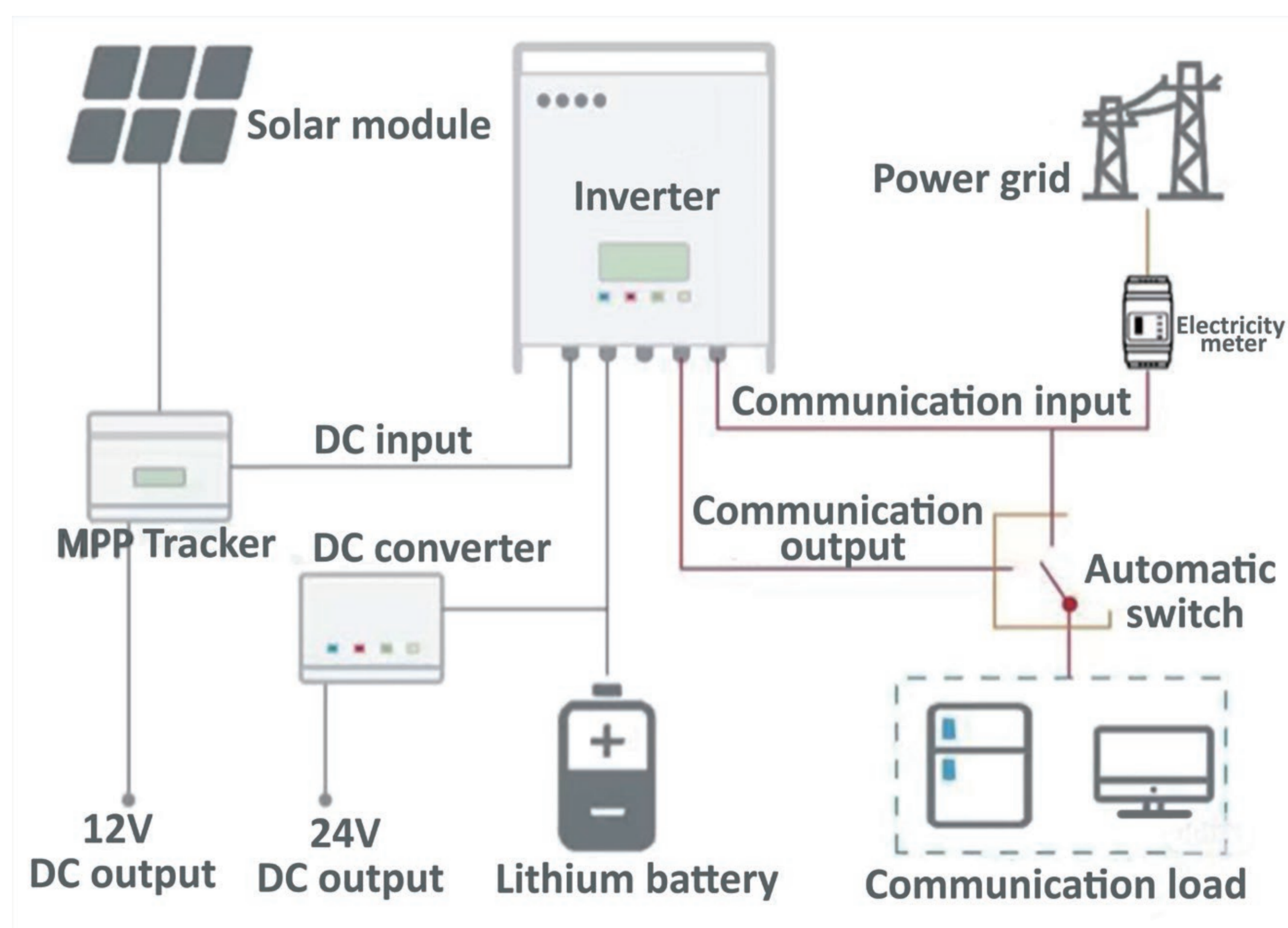
This manual does not constitute any form of warranty. The company assumes no liability for any loss, damage, or expense arising directly or indirectly from the installation, operation, use, or maintenance of the modules. The company is not responsible for any infringement of patents or third-party rights caused by the operation and maintenance of the modules.

02

PV | Requirements for O&M Personnel

2.1 Professional Skills

O&M personnel must possess basic knowledge of electrical engineering, including DC/AC circuit principles, PV module electrical characteristics (such as I-V curves and temperature coefficients), and inverter operating principles. They must be familiar with PV system architecture (string, centralized, etc.) and common equipment parameters. They must be able to identify module types (monocrystalline, bifacial, thin-film, etc.) and identify common faults such as hot spots, PID degradation, and hidden cracks.



Hot spot



PID decay



Hidden crack

2.2 Safety Awareness and Operating Standards

Qualified personal protective equipment (PPE) must be worn during all work, including insulating gloves, insulating shoes, safety helmets, and arc-proof clothing. Outdoor electrical work must be suspended in rainy or humid environments.

Strictly follow the "power off → electrical test → grounding → tag out" procedure.

Strictly prohibit touching live parts with bare hands. Use the MC4 dedicated tool for string plugging and unplugging.

Be familiar with emergency response plans for fire, electrical leakage, and electric shock, and participate in fire drills regularly.

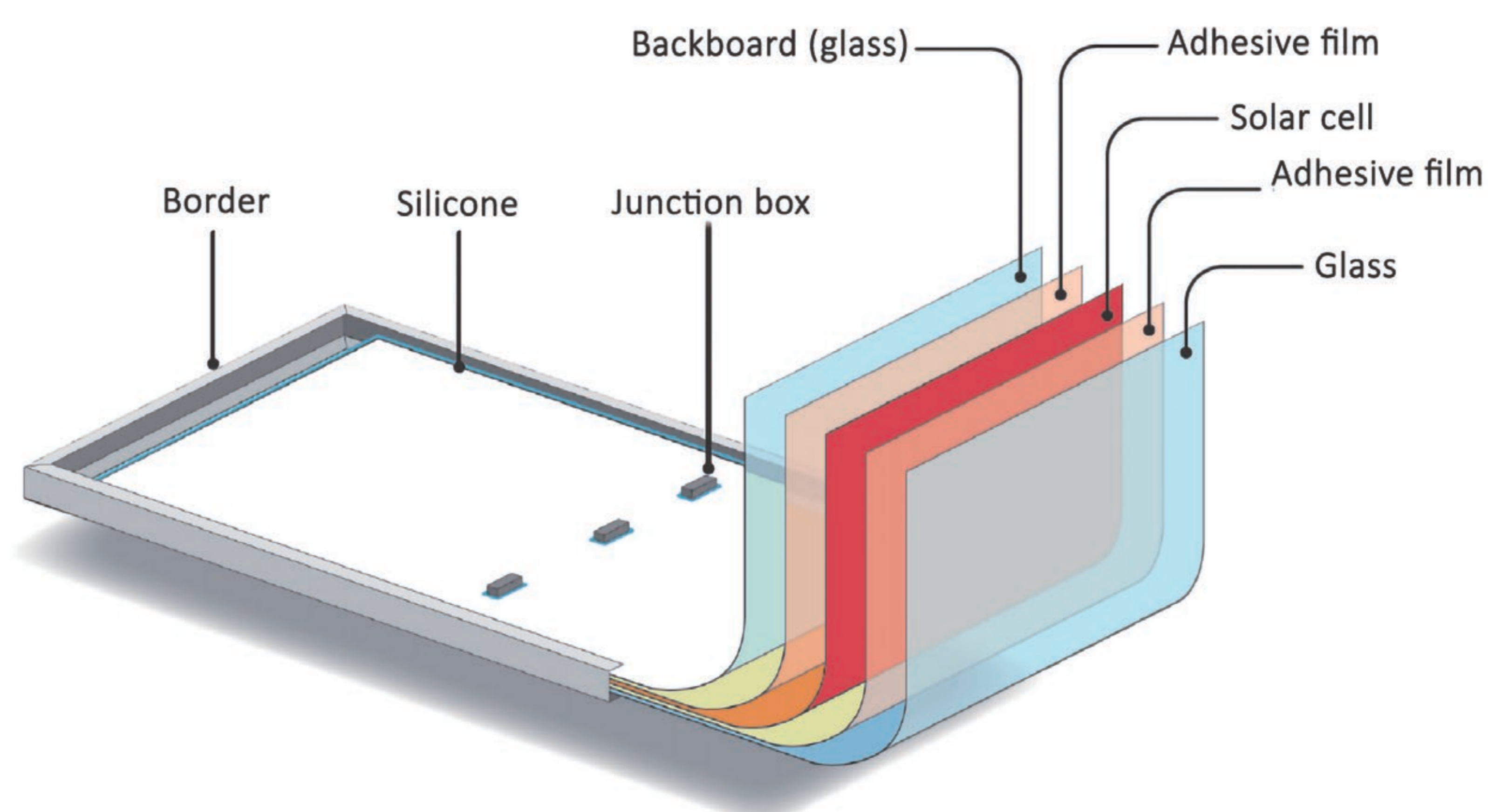


03

PV Modules Inspection

3.1 PV Modules Introduction

PV modules are primarily composed of eight materials: cells (the core power generating unit), encapsulant film (such as EVA, for bonding and protection), backsheet (used in single-glass module for weather-resistant insulation), PV glass (used in double-glass modules for high light transmittance protection), ribbons/busbars (current collection and conduction), frame (aluminum alloy, for support and sealing), junction box (current output and safety protection), and silicone (bonding and sealing).



Component Construction Diagram

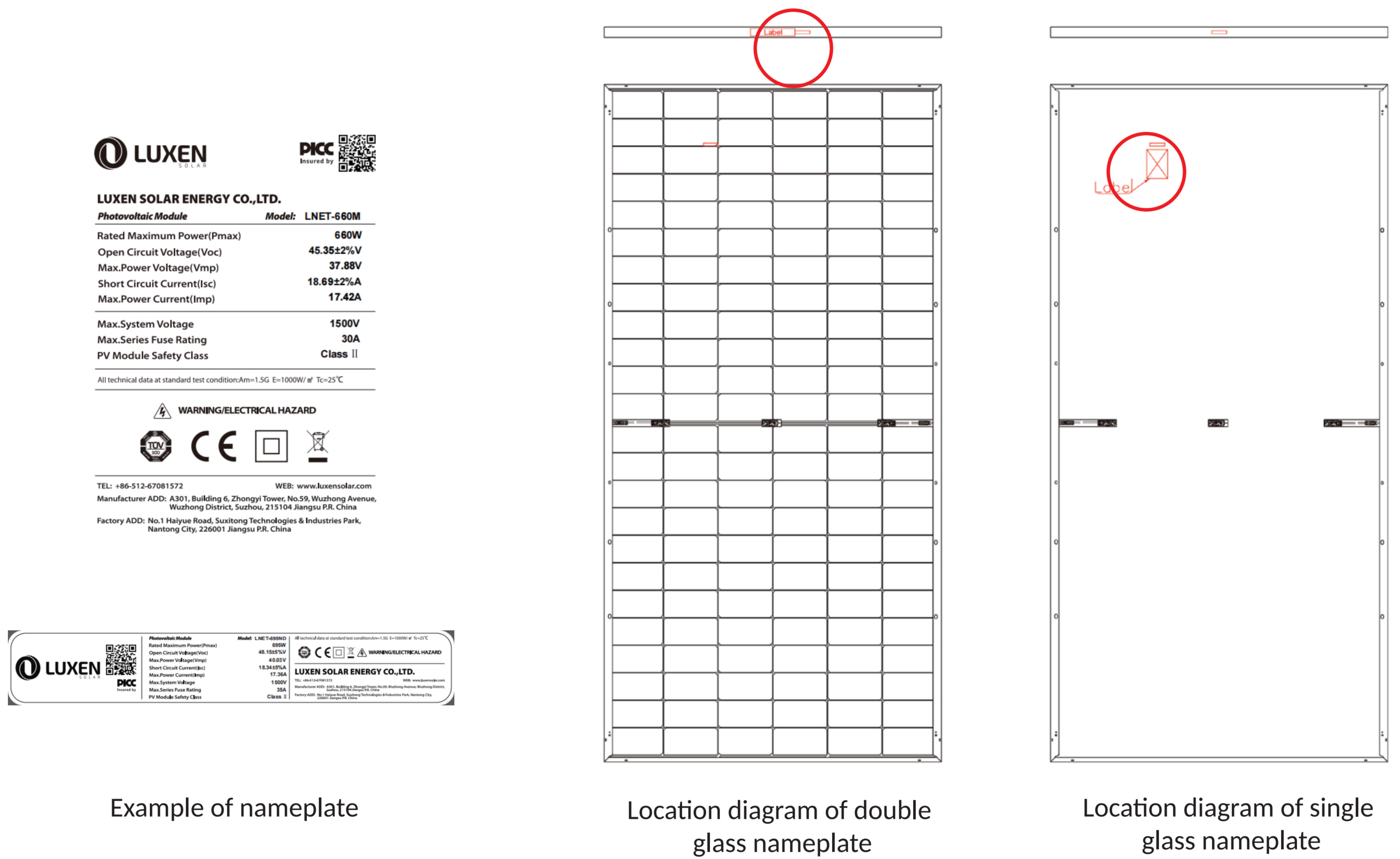
Each module is affixed with two labels for identification and tracking:

(1) Nameplate

Location: On back of the module or short side frame

Appearance: Rectangular for single glass module, long strip for double glass module.

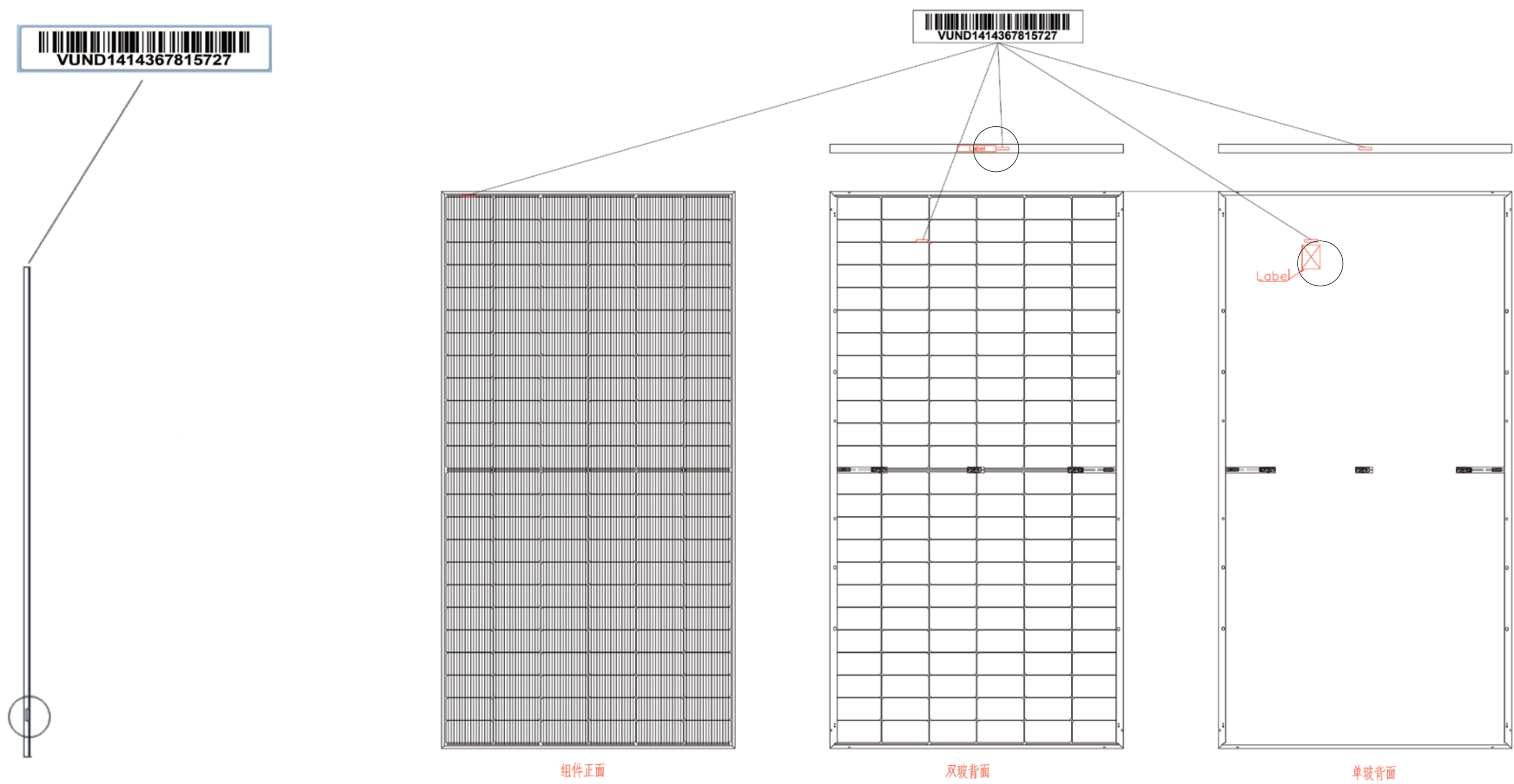
Information: Product type, rated power, rated current, rated voltage, open-circuit voltage, short-circuit current under standard test conditions (STC), as well as key parameters such as certification markings and maximum system voltage.



(2) Barcode (Serial Number)

Features: Unique identification mark, inserted before lamination, and can not be tampered with or removed.

Location: Placed near the nameplate, at the lower back of the module, or short side profile, with consistent markings in multiple positions.

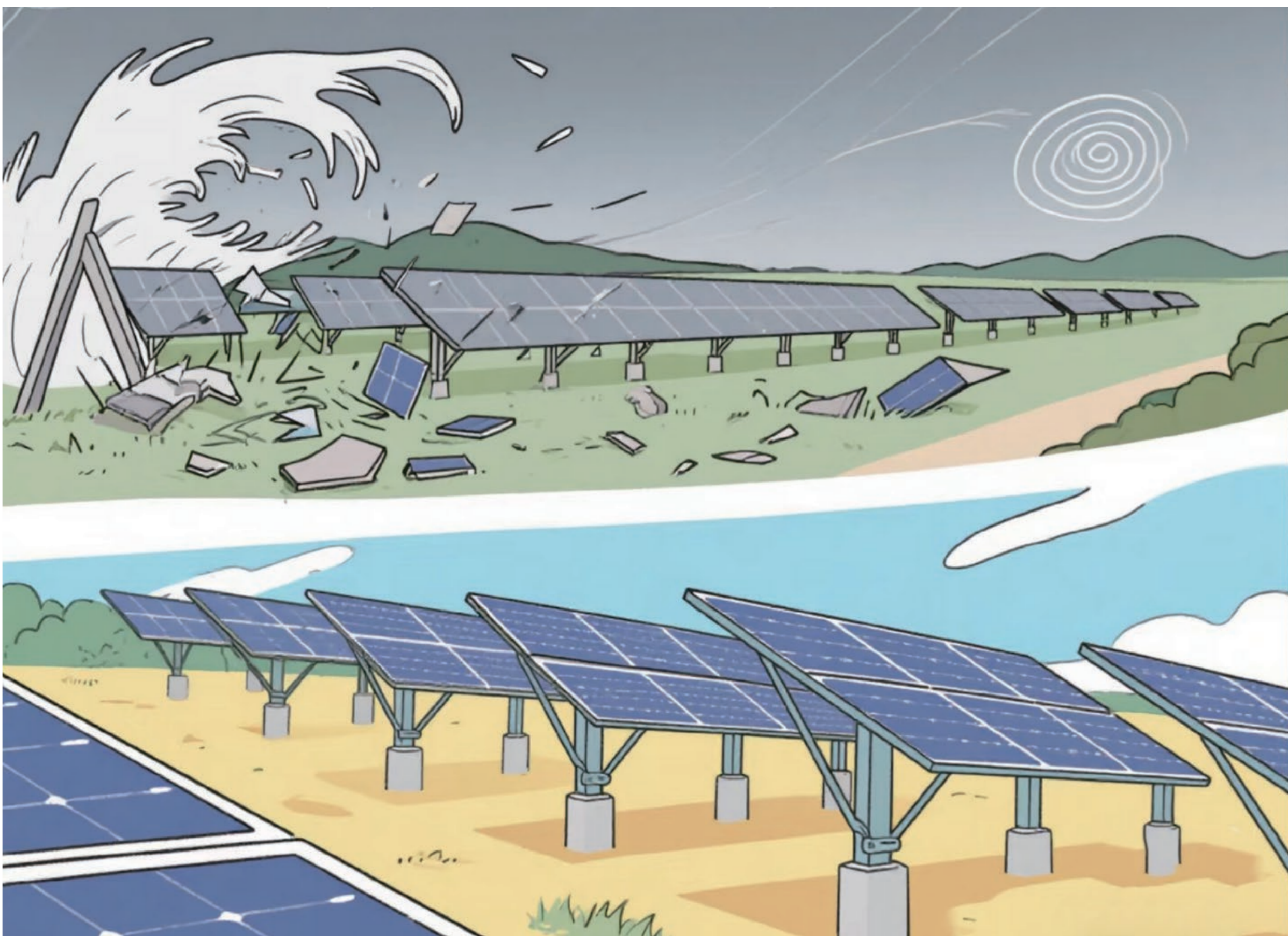


3.2 Regular Inspection

To ensure stable and efficient operation of the power plant, it is necessary to conduct regular and on-demand inspections of PV modules and combine them with intelligent monitoring methods. Specific suggestions are as follows:

Routine inspection: Carry out comprehensive inspections at least three times a month according to established routes and items.

Special inspection: Inspection should be increased in the event of severe weather such as thunder, rain, strong winds, floods, severe cold, when the equipment is overloaded or operating with a defect, or when new equipment is being tested.



Inspection Methods and General Handling Recommendations:

Visual inspection is the fundamental method.

Many electrical faults (such as issues with cables, connectors, or junction boxes) may cause insulation problems or abnormal current/voltage. It is recommended to first use the monitoring platform to identify the general area of the issue, and then conduct on-site detailed troubleshooting.

If any issue is found that cannot be resolved independently or is severe (such as broken glass, scratched backsheet, severely deformed/torn/corroded frame, or burned junction box), be sure to mark the abnormal module and promptly consult Luxen customer service or qualified professionals for proper handling.

Reminder: Ensure proper safety protection before starting any operation. If you encounter a problem beyond your handling capability, please contact a professional immediately.

In addition, if the plant operator or system integrator has stricter professional regulations, it is recommended to comply with those regulations.

By following the above arrangements, the safety and performance of the power plant can be better ensured.

3.3 PV Modules Inspection

Inspection Items:

Glass: Check for breakage and cracks.

Backsheet: Check for burns, bulges, noticeable color changes, and bubbles (especially those forming connecting channels).

Frame: Check for deformation and corrosion, and ensure bolts are tight.

Junction Box: Check for deformation, twisting, cracking or burning, whether the seal is good, and whether the terminal is firm and free of corrosion.

Cables: Check the MC4 connector for loose connections and signs of burns. Check the cable sheath for damage or deterioration.

Marking: Check that the live warning label and nameplate on the component are legible and intact.

Inspection Items	Inspection Content/Standards	Recommended cycle (for reference)
Module Appearance	Check for damage, cracks, corrosion, stains, and obstructions (such as bird droppings or leaves).	Once Every Month
Electrical Warning Labels	Check for missing or damaged labels, and replace immediately if any are missing.	Regular Inspection
Cables	Check for damage, water immersion, and aging; route and secure cables properly to avoid water accumulation or animal bites; use the monitoring platform to help locate insulation or current/voltage faults.	Regular Inspection
Connectors	Check for overheating, damage, contamination, water immersion, and corrosion; ensure connections are tight; avoid contact with alkane substances; secure cables to prevent connector immersion.	Regular Inspection
Junction Boxes	Check for deformation, twisting, cracking, or burning; avoid direct sunlight, water accumulation, and cable tension; check lightning protection grounding; shading may cause abnormalities.	Regular Inspection
Fasteners	Check if bolts and clamps are loose; strengthen inspections before and after extreme weather; use anti-loosening screws in high-frequency wind vibration areas.	Regular Inspection
Module Frame	Check for deformation, tearing, or corrosion; slight deformation not affecting installation and use can be marked and continue to be used; severe deformation, tearing, or corrosion must be marked and reported to professionals.	Regular Inspection
Glass	Check for breakage; strengthen site management to prevent impacts; prevent maintenance vehicles from kicking up gravel or birds dropping objects.	Handle When Occurs
Backsheet	Check for scratches; if scratched, replace the module or consult a professional.	Handle When Occurs
System Performance Abnormalities	Monitor and compare string current/voltage (deviation >5%) or combiner box power output (difference >15%), locate abnormalities through the platform and conduct on-site troubleshooting.	Real-time Monitoring, Immediate Handling

3.4 Electrical Safety Inspection

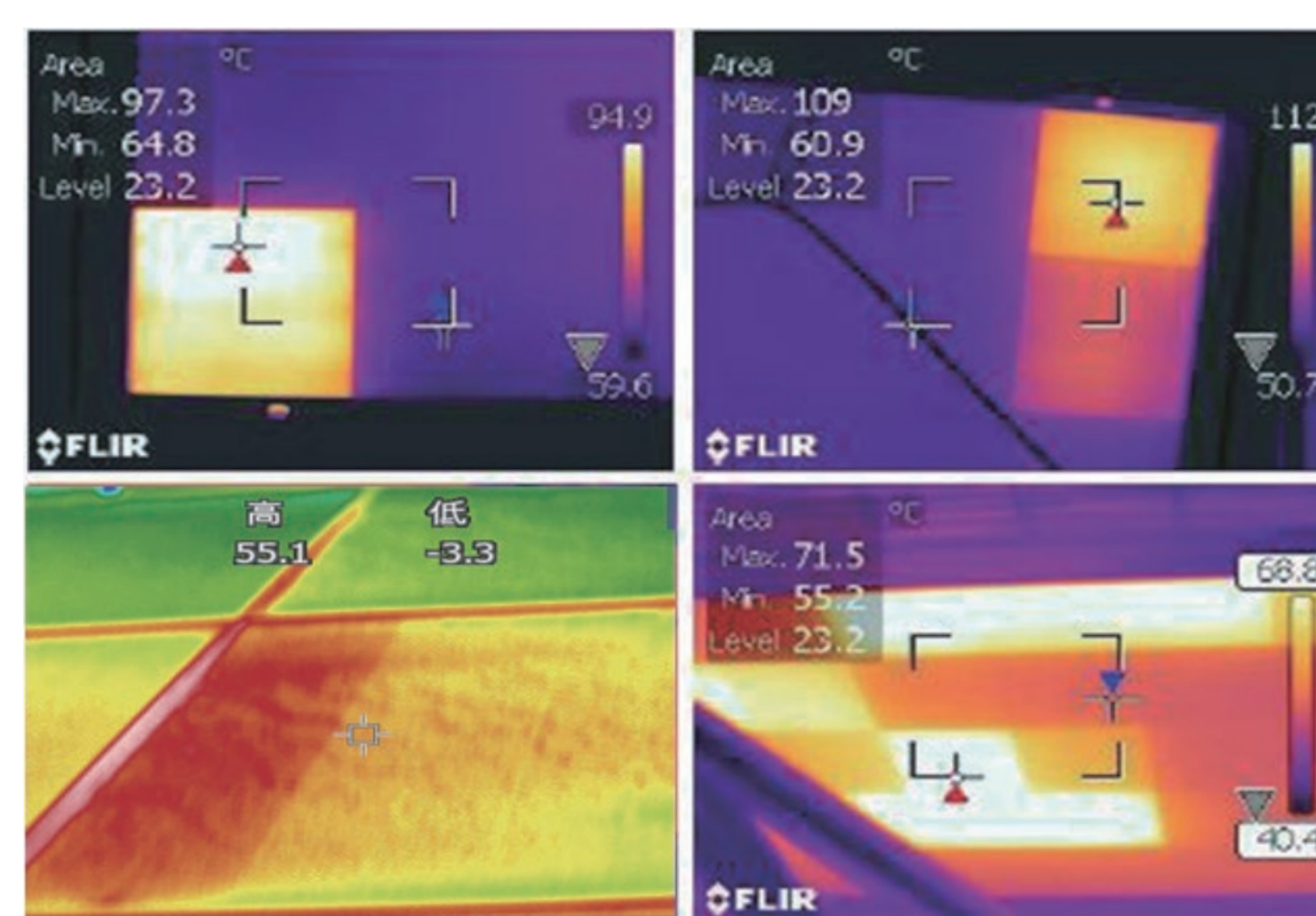


To ensure the safe and efficient operation of power plants, it is recommended that power plants, if possible, be equipped with professional testing equipment (such as module characterization testers, DC clamp meters, multimeters, insulation resistance testers, infrared thermometers, infrared thermal imagers, etc.) and regularly conduct sampling tests on the operating temperature and insulation performance of photovoltaic modules.

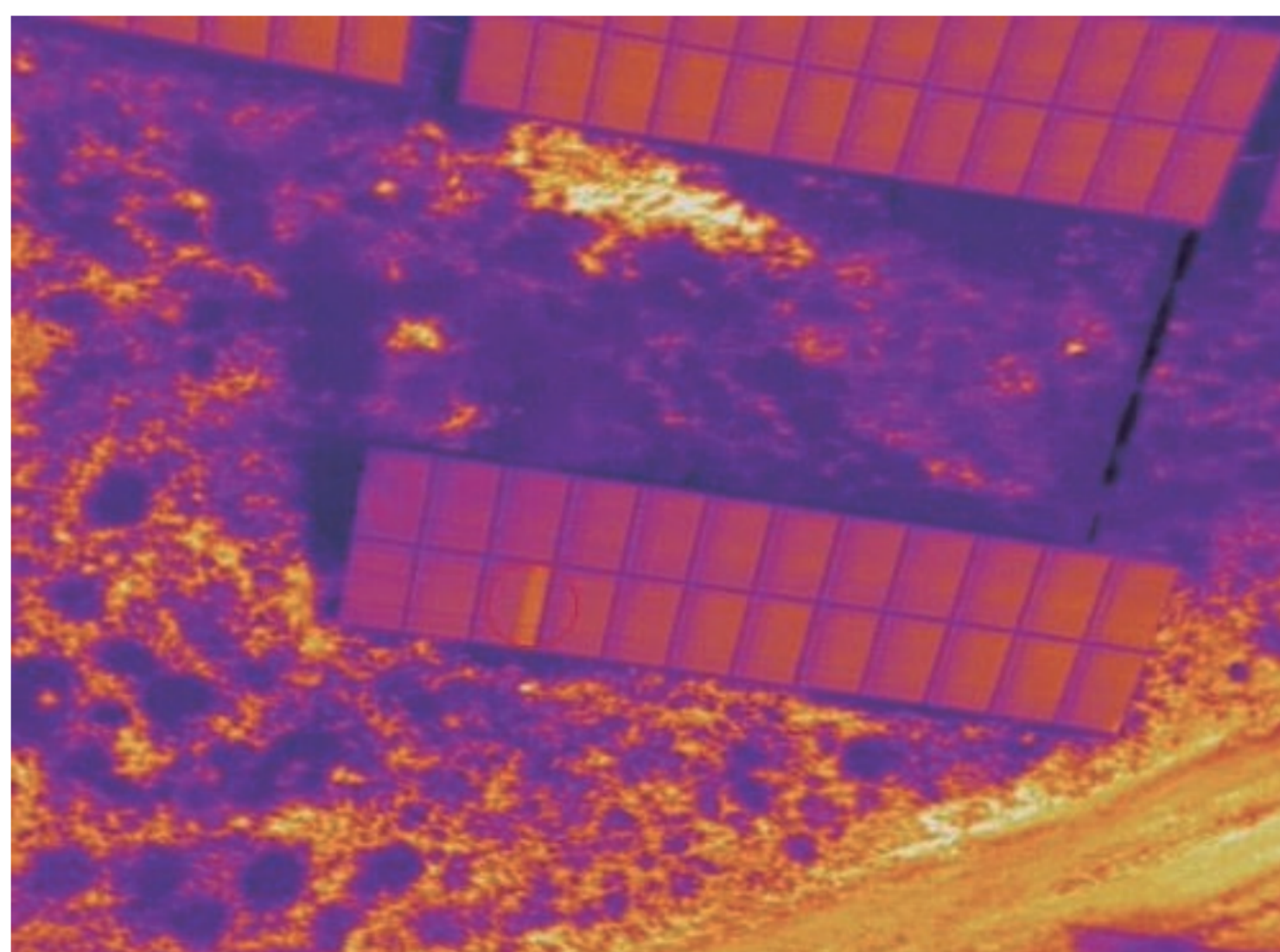
Thermal Imaging Inspection:

Regularly scan the entire module using an infrared thermal imager to identify abnormal hot spots.

Use an infrared thermal imager to scan the module and detect surface temperature differences. This allows for quick detection of hot spots, internal defects, or wiring faults.



Handheld infrared thermal imaging test



UAV infrared thermal imaging test



Insulation meter

Insulation resistance test:

Use a megohmmeter to measure the insulation resistance between the positive and negative terminals of the module and the ground. It should be greater than 2 megohms.

3.5 Bracket and Grounding Inspection

Bracket inspection: Check all bolts, welds and bracket connections to ensure they are secure and reliable, and to ensure there is no deformation, misalignment or loosening. The anti-corrosion coating on the bracket surface should not crack or fall off.

Grounding Check: For modules with metal frames, the frame must be securely grounded. Check that the frame and bracket are properly connected, with the contact resistance between them no greater than 4Ω . Check that the grounding wire is securely connected and free of rust and breakage.

Tightening inspection: The busbar bolts in the combiner box and key connecting bolts of the bracket should be tightened every year.





04

Cleaning and Maintenance of PV

4.1 Cleaning of PV Modules

Cleaning Conditions:

When the PV array output falls below 85% of its initial output (at the end of the last cleaning), cleaning should be considered. Cleaning should be performed when the irradiance is less than 200W/m^2 (e.g., early morning, evening, or on cloudy days). Avoid using cold water on panels heated by sunlight, which may cause glass cracking. Panel cleaning is strictly prohibited in winds exceeding force 4, heavy rain, or snow.

Cleaning Method:

Wipe with a dry or damp, soft, clean cloth. Do not use corrosive solvents or hard objects. Do not use liquids with a large temperature difference from the components to clean the components. For large power plants, consider using specialized cleaning robots or equipment.

Safety Tips:

Before cleaning, ensure the system is free of electrical leakage and wear protective insulation. Prevent water from entering the junction box or electrical connectors.

4.2 Cleaning Requirements

Develop a scientific cleaning cycle based on the environmental conditions of the power station location (such as dust, bird droppings, rainfall frequency, etc.). Usually rainwater can play a certain cleaning role, but in dry and dusty areas, manual cleaning frequency needs to be increased.

4.2.1 Cleaning Water and Detergent Requirements

PV panel cleaning has clear requirements for water use, operation, and detergent use, aiming to ensure cleaning effectiveness while protecting panel safety and power generation performance. The following are the key points:

Category	Requirements and Standards	Precautions / Risk
Cleaning Water	Domestic water can be used directly. If using other water sources, they must meet the following:	It is not recommended to use water with high mineral content, as this may cause mineral deposition and reduce the light transmittance of the glass, thus affecting the power generation.
	pH: 6–8 (neutral)	
	Conductivity: $\leq 3000\ \mu\text{S}/\text{cm}$	
	Total Dissolved Solids (TDS): $\leq 1000\ \text{mg}/\text{L}$	
	Water hardness (as CaCO_3): 0–450 mg/L	
	Turbidity: 0–30 NTU	
	Chlorides / Salinity: 0–1000 mg/L	
Water Temperature and Environment	The temperature difference between cleaning water and module surface must not exceed 10°C .	To prevent glass breakage from thermal stress.
	Do not clean if ambient temperature is below 5°C (to avoid freezing and glass cracking).	
	Prefer cleaning in early morning, evening, nighttime, or overcast conditions when irradiance is low (recommended $< 200\ \text{W}/\text{m}^2$).	Avoid cleaning under strong light as this may cause electric shock, module damage or thermal stress.
Water Pressure Control	When using pressurized water, the pressure exerted on the module glass surface must not exceed 0.7 MPa.	Excessive water pressure may damage modules.
Use of Cleaning Agents	Prefer clear water. Only when clear water can not remove contaminants, consider a small amount of commercial glass cleaner, alcohol, or methanol as auxiliary agents.	
	These can permanently damage surface materials, coatings, and seals, causing severe performance loss or safety hazards.	These can permanently damage surface materials, coatings, and seals, causing severe performance loss or safety hazards.
	After using any auxiliary cleaning agent, please rinse thoroughly with compliant clean water.	
	Do not use steam or accelerate cleaning with corrosive chemical reagents.	
Special Cases	In extreme climates or heavily polluted environments where chemicals are unavoidable, please contact Luxen’s after-sales team first to inquire about specific operating specifications and requirements.	Non-standard chemical cleaning may damage modules and affect warranty.



4.2.2 Precautions during Cleaning Process

Category	Requirements and Suggestions	Precautions / Risk
Personal Protection	Operators must wear clean cleaning gloves during operations.	Do not touch module glass with bare hands (to avoid fingerprints / stains that reduce light transmission).
Prohibited Tools	Do not use any tool that may scratch glass, such as blades, metal tools, scouring pads, steel wool, or other abrasive materials.	Such hard materials will cause permanent scratches on module's surface and reduce power output.
Recommended Tools and Materials	Please use soft, non-damaging materials, for example:	
	Soft foam materials, non-woven cloth, soft sponges.	All tools must be soft to avoid abrasion.
	Soft brush (such as nylon bristles with a recommended diameter of 0.06 - 0.1mm) and soft broom.	Nylon bristles are more common, but attention should be paid to their wear resistance. PBT or nano-composite bristles may be better in durability and protection.
	If using a sponge, be sure to use the soft side and avoid the hard part of the back coming into contact with the modules.	
cleaning equipment	Automatic cleaning equipment, such as cleaning robots, is permitted.	
	Operators must strictly follow the device's instructions.	Ensure device operation will not cause mechanical damage or excessive pressure on modules.
	If you are unsure whether the automatic equipment you are using is compatible or there is a risk of damage, be sure to consult Luxen customer service in advance.	Non-compatible or improper automated cleaning may cause micro-cracks or breakage.

4.2.3 Special environmental cleaning methods and risks

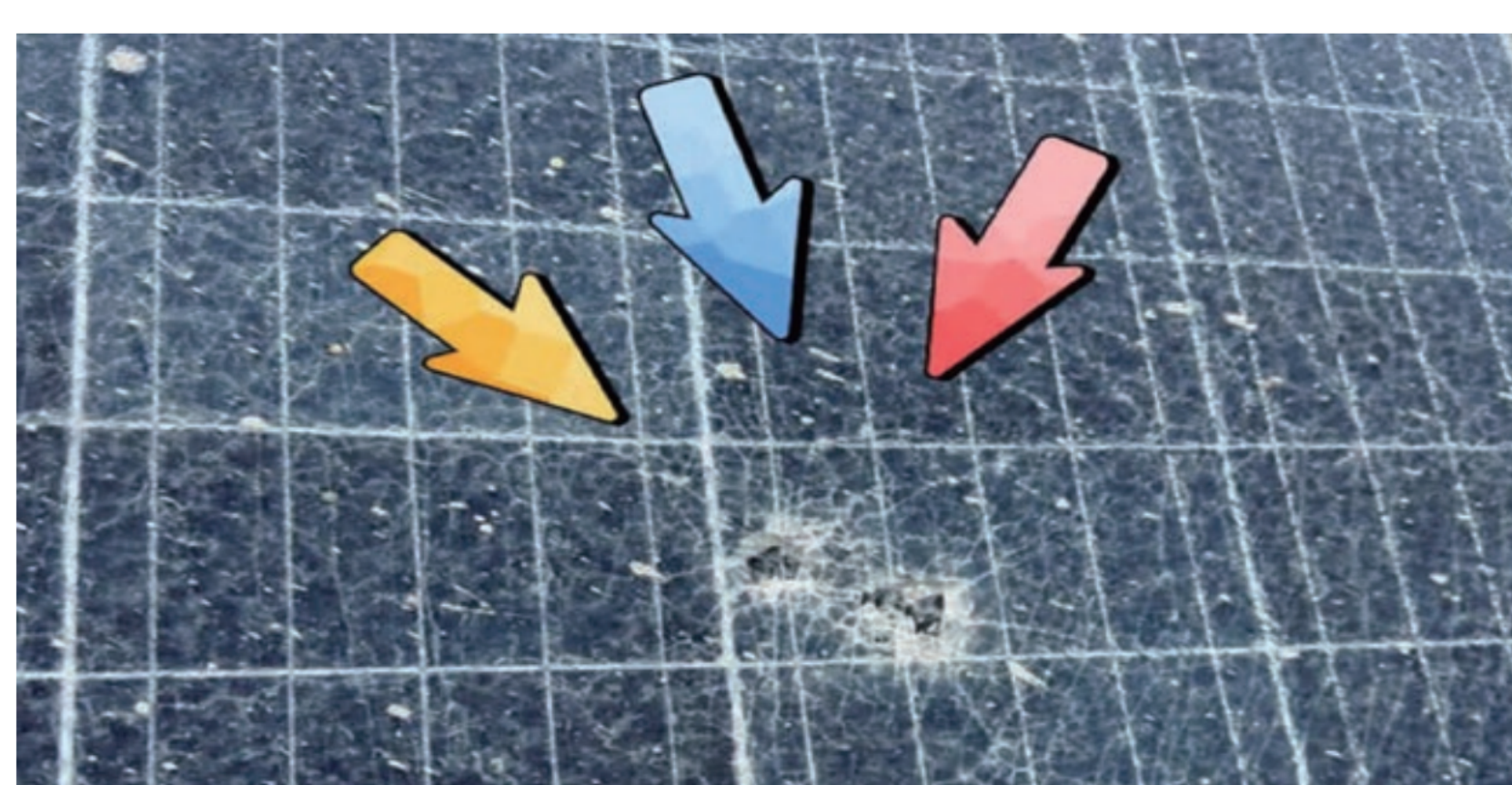
Category	Specification Requirements	Key Causes / Risks
Module Type and Cleaning Area	<p>It is recommended to clean the backside of the bifacial module;</p> <p>It is not recommended to clean the backside of the monofacial module.</p>	<p>The backside of bifacial modules receives sunlight, which contributes to power generation. Keeping it clean helps improve efficiency.</p> <p>Not cleaning backsides of monofacial modules is for safety and because it is unnecessary.</p>
Electrical Safety	<p>Never allow running water to splash onto cables, junction boxes, or connectors.</p> <p>Ensure all connectors remain clean and dry.</p>	Prevent electric shock, short circuits, and fire risk.
Module Condition and Operation	<p>Do not clean modules with broken glass or torn frames, or modules with damaged cable insulation.</p> <p>Do not step on modules.</p>	Cleaning when the module is damaged or the cables are exposed can cause a high risk of electric shock; stepping on the module may cause glass cracks and damage the cells.
Weather Condition	It is strictly forbidden to clean modules under severe weather conditions such as strong winds (usually level 4 or above), heavy rain, and heavy snow.	Working in bad weather can lead to personal safety issues (such as increased risk of slipping, falling, and electric shock), and modules can be easily damaged.
Snow Removal	<p>When removing snow, use a soft cloth to gently clear all snow.</p> <p>Avoid removing only partial snow (which creates a “ patchy ” pattern).</p> <p>Do not forcibly remove frost and ice.</p>	<p>“Partially covered with snow and partially uncovered” will cause hot spot effects, seriously damaging the modules;</p> <p>Forcible removal can scratch or shatter module glass.</p>
Cleaning Effectiveness Standard	After cleaning, module glass surface should be free of dust and dirt and meet cleanliness requirements.	This is a direct visual criterion for measuring the effectiveness of cleaning work.

Before any cleaning operation, make sure the system is powered off, wear insulating gloves and insulating shoes, and take personal safety precautions.

05

Troubleshooting and Emergency

5.1 Common Failures



Glass shattering, back panel burnt, obvious color change:
Immediately isolate the faulty module and arrange for a replacement.



Junction box damaged (deformed, cracked, burned):
Replace the junction box or the entire module immediately.



Hot spots:
Check and remove obstructions. If there is a problem inside the module, replace it.



Abnormal current/voltage:
Check the connection lines, MC4 connectors, combiner boxes, and circuit breakers.



PID effect:
Check the voltage between the module and ground. If necessary, enable the PID repair function or install an anti-PID module.

5.2 Emergency Plans

Fire:

Immediately disconnect all power sources (DC and AC);

Use a dry powder or carbon dioxide fire extinguisher to extinguish the fire. Do not use water to extinguish electrical fires;

Evacuate personnel and call the fire department.

Natural disasters (typhoons, heavy rain, snowstorms, etc.):

After the disaster, inspect the azimuth, inclination, and overall structural stability of the support immediately. Check modules and electrical equipment for water damage, displacement, and other signs.

Electric shock:

Immediately disconnect the power source or use an insulating object to isolate the victim from the power source.

Provide first aid to the victim and call emergency services.

The whole Power Plant Outage:

Follow the pre-defined emergency plan for the whole power plant outages, checking the status of the power grid, switches, and key equipment.





06

Records and Document Management

6.1 O&M Records

Keep detailed records of the entire process of each inspection, cleaning, maintenance, and troubleshooting, including time, personnel, equipment status, problems found, measures taken, etc. Use standardized forms such as "Power Plant Daily Inspection Form" and "Equipment Maintenance Ledger".



6.2 Data Analysis

Regularly analyze power generation data, fault records, and performance test results to assess module health and overall power plant performance, and optimize O&M strategies.

6.3 Document Management

Establish and properly preserve equipment technical files (including module specification sheet, factory inspection reports, installation records, etc.), design and construction drawing, all O&M records and fault analysis reports. Encourage the use of digital management systems for file management.

KEN

07

Safety Precautions

Safety Precautions for PV Modules O&M:

The O&M of PV modules must strictly follow the product documentation (including installation manuals, warranty documents, module specification sheet and certification standards), and comply with national laws and regulations, local regulations and standards and specification of the power industry (such as the Occupational Safety and Health Law, the Environment Protection Law and relevant national standards) to ensure the safety of personnel and PV system.

7.1 Work Safety

To ensure safe and efficient O&M of PV module and protect the safety of equipment and personnel, please be sure to follow the following core safety regulations:

Category	Safety Prohibitions	Key Causes / Risks
Personnel Protection	Wear protective clothing and helmets; avoid clothing or tools with parts that can easily get caught.	Prevent damage or scratches from the corners of the bracket or modules frame, and avoid tripping accidents during operation.
Module Handling	Do not lift modules by grabbing junction boxes or cables.	It may detach junction boxes or damage cables, causing electrical faults.
Module Load-bearing	Do not stand or walk on modules.	It may cause glass cracks and cells cracks, resulting permanent damage.
Module Integrity	Do not attempt to disassemble modules or remove nameplates or any component.	It may damage the module and void the product warranty.
Module Surface	Do not paint or apply adhesives to module surfaces.	It may damage surface material, affect light transmittance and heat dissipation, lowering efficiency or causing hot spots.
Module Backside	Avoid scratching the backside or glass.	It may damage to insulation and sealing performance may cause leakage or water seepage risks.

Category	Safety Prohibitions	Key Causes / Risks
Frame Modification	Do not drill holes into module frames without authorization.	It will significantly reduce the mechanical strength and load-bearing capacity and may cause corrosion, resulting in the invalidation of the warranty.
Module Repair	Any repair of modules without permission is strictly prohibited.	Non-professional repair may cause further damage or safety hazards. Please contact professionals.
Connector Protection	After installation, connectors should be connected promptly or protected temporarily.	Prevent moisture, dust, organisms and other foreign matter from entering, thus avoiding poor connector contact, malfunction or damage.

7.2 Electrical Safety



When operating, wear insulated shoes, low-voltage insulating gloves, and use insulated tools.

PV modules generate electricity when exposed to sunlight. Before operating, be sure to shield the modules or disconnect the wiring, and perform a voltage test to confirm there is no voltage.

Keep connectors dry and clean. Improper connections can cause arcing and electric shock.

7.3 Environment Safety



Flammable or explosive items must not be stacked around the modules. Ensure proper ventilation and heat dissipation of the equipment.

Effective measures should be taken to prevent snakes, rats, and other small animals from entering the wiring holes of the equipment.

08

Supplementary

Manual Review and Update

Regularly review and update manual contents based on equipment changes or technological developments.

This manual is a general guide. In actual operation, please be sure to strictly adhere to the specific safety regulations of your power plant and the latest instructions from the equipment manufacturer.

Safety first, prevention first.

Revised version and date

Sep. 2025

Create and Enjoy a Green Zero-carbon Future

Phone:400-828-2877
Email:sales@luxensolar.com
Website:www.luxensolar.com

Nantong Manufacturing Factory: 1 Haiyue Road, Nantong, Jiangsu Province, China
Suzhou Sales & Marketing Center: A301 Zhongyi Building,59 Wuzhong Blvd, Suzhou, Jiangsu Province, China



Wechat Official Account



Wechat Channel



Instagram



Linkdeln