SolarPega & SolarPegaF Series

Light-Rigid PV Module O&M Manual

Shandong ZKFN Solar Technology Co., Ltd.

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1. Manual Overview, Rights and Responsibilities

1.1 Scope of Application

This manual is the official O&M guidance document issued by Shandong ZKFN Solar Technology Co., Ltd. (hereinafter referred to as "ZKFN SOLAR") for the SolarPega series (SolarPega, SolarPegaL) and SolarPegaF series (SolarPegaF, SolarPegaFL) TOPCon lightweight rigid crystalline silicon PV modules (hereinafter referred to as "Modules"). This manual covers all operational aspects throughout the entire lifecycle of the PV system after grid-connected commissioning, including: routine inspection and specialized testing, module cleaning, fault diagnosis and location, module repair and replacement, emergency response, and O&M records management.

This manual is intended for system integrators, EPC general contractors, O&M service providers, and professionally qualified personnel engaged in the operation and maintenance of the above-mentioned module series. Any person responsible for the operation, inspection, or repair of this product is obligated to read, fully understand, and strictly comply with all provisions of this manual before commencing work. Failure to comply with the operating procedures, safety precautions, and technical specifications set forth in this manual may result in serious personal injury or property damage. The operation and maintenance of PV modules requires professional skills and may only be performed by qualified personnel holding the appropriate certification. The O&M entity must provide written notification of the safety and maintenance essentials contained in this manual to the end customer.

1.2 Disclaimer

ZKFN SOLAR reserves the right to modify this manual without prior notice due to product technology upgrades, process improvements, or standards updates. The latest version of this manual will be published simultaneously on the ZKFN SOLAR official website download center. Customers and O&M parties are responsible for proactively checking and ensuring the use of the latest version. Any operational deviations resulting from the use of an outdated version of this manual shall be the sole responsibility of the user.

Failure by the customer to follow the requirements set forth in the O&M manual (including changes published on ZKFN SOLAR's official website during the O&M period) during module operation and maintenance will result in the voiding of the limited product warranty provided to the customer.

ZKFN SOLAR makes no warranty, express or implied, with respect to any information contained in this manual. Users and O&M personnel must conduct on-site technical surveys of the project to ensure that the O&M methods adopted comply with local laws, regulations, and building codes.

1.3 Scope of Liability

Regardless of whether module O&M is performed in accordance with the instructions in this manual, ZKFN SOLAR assumes no legal liability for any damage arising during the O&M process (including but not limited to personal injury and property damage resulting from module handling and system maintenance).

In the event of any discrepancy between different language versions of this manual, the Chinese version shall prevail.

This manual is provided solely for O&M operational guidance. No statement in this manual, whether express or implied, shall constitute a warranty certificate.

1.4 Warranty Terms

All ZKFN SOLAR SolarPega and SolarPegaF series products are covered by a 15-year product warranty and a 30-year linear power warranty. The specific warranty coverage, claim procedures, and exclusion clauses shall be governed by the official warranty document provided at the time of product purchase.

Key auxiliary materials used with the modules, including clamps, structural adhesives, and MC4-compatible connectors, must use specification models recommended or certified by ZKFN SOLAR to ensure overall system compatibility, reliability, and safety. Product or system damage caused by the use of non-certified hardware is not covered under warranty.

1.5 Technical Support Information

For more detailed technical support documentation, project-specific solution coordination, or assistance with abnormal O&M issues, please contact ZKFN SOLAR through the following official channels:

Service Hotline: (+86) 400 6768 100 (Office Hours: 8:30-17:30, Beijing Time)

Technical Support Email: tech-support@zkfnsolar.com

Official Website: www.zkfnsolar.com

Manufacturing Base Address: Building 1, Xinshenglin, Lvhaihui Intelligent Manufacturing Industrial Park, Jining Economic Development Zone, Jining City, Shandong Province

2. O&M Safety Operating Procedures

2.1 General Safety Warnings

1. All O&M work must be performed in full compliance with local and regional regulations as well as applicable national or international electrical standards.
2. Electric Shock and Burn Hazard: PV modules are DC power generating devices. When their surfaces are exposed to light, DC voltage will be present at the positive and negative terminals and connectors even if they are not connected to a circuit. The voltage of a PV array consisting of multiple modules connected in series can reach levels that endanger personal safety. Personnel who have not received professional training or authorization are prohibited from contacting the module's terminals, connectors, or exposed live parts in any manner. Contact with live components may result in severe burns or fatal electric shock.
3. Prohibition of Load-Break Operations: Before performing any module replacement, wiring, or system modification work, it is essential to first ensure that both the DC-side and AC-side systems are completely de-energized, and to implement strict anti-reclosure and de-energization verification measures. It is prohibited under any circumstances to disconnect connectors or electrical connections under load. Load-break disconnection will generate a hazardous and destructive DC arc, which may cause fire, equipment damage, and serious personal injury.
4. Handling of Damaged Modules: Modules found with appearance damage during O&M inspections (including but not limited to surface penetration, cracking, backsheet scratches with penetration, junction box cracking, or internal water ingress) shall be immediately isolated and scheduled for replacement. Damaged modules are irreparable and pose an extremely high risk of electrical leakage and electric shock, as their insulation performance has completely failed. It is prohibited for any reason to disassemble modules, remove module components, or modify the wiring of bypass diodes. Module junction box covers must remain securely closed at all times.

5. Positive-Negative Short Circuit Risk: It is prohibited to directly connect the positive and negative connectors of a single module, as this will cause a module short circuit. Before performing O&M work, all connector insulation plugs or sealing rings must be inspected and confirmed to be intact and properly seated, to prevent short circuits caused by insulation failure, which could lead to fire or electric shock hazards.

6. Environmental and Electrical Parameter Limits: The designed stable operating ambient temperature range for the modules is -40°C to +85°C. The maximum system open-circuit voltage under any expected minimum ambient temperature must not exceed the maximum system voltage of DC 1500V indicated on the module product label. Operation beyond rated parameters is prohibited during O&M.

7. Fire Safety: If a fire occurs at the O&M site, under conditions where it is safe to do so and without risk to personnel, the power supply of the entire PV system (including both DC and AC sides) must first be disconnected. Subsequently, firefighting shall be conducted in accordance with electrical fire codes using non-conductive extinguishing agents such as dry powder or carbon dioxide. It is prohibited to directly spray water or foam onto the modules and electrical system without first disconnecting the power supply.

8. Application Class and Warning: This series of modules is Application Class A (equivalent to IEC 61730-1 Safety Class II), suitable for systems accessible to the public. When the system open-circuit voltage exceeds 50V, according to safety regulations, prominent "Danger: Electric Shock" warning signs must be posted near string connection devices and at easily accessible locations such as inverters.

2.2 O&M Personnel Safety Requirements

1. Qualification Requirements: All personnel responsible for the operation, inspection, and repair of PV systems must have completed professional PV system O&M training, hold valid relevant qualification certificates (including but not limited to low-voltage electrician certificate, high-voltage electrician certificate, work-at-height certificate), and be thoroughly familiar with all safety specifications in this manual and relevant local government regulations.

2. Two-Person Work Rule: To minimize risks associated with solo operations (such as accidental electric shock, falls from height, etc.), all on-site inspections, cleaning, repair, and wiring work must be performed by at least two persons working together. Solo high-risk operations are prohibited.

3. Personal Protective Equipment (PPE): O&M personnel must correctly wear certified personal protective equipment during operations, including but not limited to: anti-slip protective gloves, long-sleeved insulated work clothing, and anti-smash insulated shoes. When working at roof edges or in any area where a fall hazard exists (height difference exceeding 2 meters), a dual-hook shock-absorbing safety harness must be worn at all times and securely attached to an independently installed lifeline or anchor point. Additionally, guardrails or safety nets should be installed below the work surface.

4. Tools and Jewelry: Only tools that meet safety standards and are properly insulated may be used during work. Wearing any metal jewelry (such as watches, rings, necklaces, bracelets, etc.) is prohibited while on duty. Such items may cause unintended current conduction leading to short circuit risks, or may scratch the module surface during work.

5. Adverse Weather: Outdoor inspections, cleaning, or repair work of any kind are prohibited under rainy, snowy, foggy, or thunderstorm conditions, or when the on-site instantaneous wind speed reaches or exceeds Force 4 (approximately 7.9 m/s). Humid

environments significantly increase the risk of electric shock. O&M personnel must ensure that all modules, tools, and electrical connection points are in a clean and dry condition before commencing work.

6. Area Control: Clear warning signs and barriers must be installed at the O&M site and module storage areas. Unauthorized personnel, children, or other irrelevant individuals are prohibited from entering to prevent accidents.

7. Light Exposure Protection: At all times, even when modules have not yet been connected to a complete system, they constitute a power source as long as they are exposed to light. It is prohibited to directly touch the junction box, cable ends, or metal contacts inside connectors with bare hands without protective measures.

2.3 Prohibited O&M Activities

To ensure module performance, personal safety, and warranty validity, the following activities are strictly prohibited during O&M operations:

1. Physical Damage and Coatings: It is prohibited to use sharp objects to scratch, strike, bend, or impact the front and back surfaces of modules. It is prohibited to apply paint, adhesives, tape, or any type of coating to any area of the module surface. It is prohibited to drill holes, cut, or grind any part of the module (unless prior written confirmation is obtained from ZKFN SOLAR professional technical personnel).

2. Cable and Connector Damage: It is prohibited to scratch, cut, crush, or pull the module's factory-installed cables and connectors in any manner. It is prohibited to expose cables and connectors to direct sunlight or water for extended periods without adequate protection.

3. Improper Handling and Pressure: It is prohibited to lift, carry, or drag modules by gripping the junction box, output leads, or connectors. Modules must be carried with both hands supporting the bottom. It is prohibited to apply improper pressure, stand, walk, climb, or jump on the module surface. It is prohibited to allow modules to collide, rub against, or impact any hard or sharp objects.

4. Artificial Light Concentration: It is prohibited to use mirrors, magnifying glasses, lenses, or other optical devices to concentrate additional sunlight or artificial light onto the module surface.

5. Water Immersion and Stacking: It is prohibited to place modules for extended periods or permanently in environments where water may accumulate or where they are continuously exposed to moisture. During all stages of storage, handling, and O&M, it is prohibited to place modules face-down, stack modules on top of each other, or apply compressive loads to modules.

6. Surface Foreign Matter and Shading: It is prohibited to apply structural adhesive, sealant, or any foreign substance onto the effective light-receiving area of the module cells during O&M. After O&M is completed, all output lines and jumper cables must be routed clearly and secured reliably. It is prohibited for conductors, clamps, or other objects to shade the effective light-receiving area of the cells.

7. Pollution Sources and Ignition Sources: It is prohibited to install continuous emission outlets or exhaust vents for oil fumes, dust, or chemically corrosive gases around the modules. It is prohibited to store open flame sources or flammable and explosive materials near the modules.

8. Improper Loading: After completing O&M inspections, it is prohibited to place any heavy objects, tools, or objects with sharp fulcrums on the module surface, to prevent long-term stress-induced damage.
9. Preventing Loosening: Modules must always remain in a securely fastened condition to withstand all potential loads (including wind and snow loads). Module loosening that pulls on connecting cables, leading to insulation failure, electrical leakage, and arcing, is a significant risk source for distributed PV systems.
10. Disassembly Prohibition: It is prohibited to disassemble modules or remove any component parts of modules. Damaged junction boxes and damaged connectors both pose potential electrical hazards and laceration hazards.

3. O&M Inspection Specifications

3.1 General O&M Requirements

3.1.1 Shading Prevention Management

During the operation of lightweight rigid PV modules, local or overall shadow shading (including but not limited to cables, terminals, vent caps, monitoring equipment, inverters, tree shadows, parapet walls, guardrails, etc.) is strictly prohibited. During O&M inspections, newly emerging shading sources must be thoroughly investigated and promptly removed.

After rain or snow events, the module surface must be inspected within 24 hours, and accumulated dust on the module surface should be rinsed off to prevent dust from mixing with rainwater to form mud stains that remain on the module surface, causing severe localized shading.

Adhere to a combination of routine inspection and specialized testing. Periodically conduct visual screening for debris shading, module appearance integrity, and junction box condition. Promptly remove localized shading objects such as surface dust and bird droppings. Implement effective shading prevention and dust accumulation prevention measures for the power station.

3.1.2 Mounting Structure Safety Inspection

1. Structural Adhesive Bonding Method: At each inspection, the condition of the bonded areas must be checked to determine whether there is adhesive opening, debonding, corner lifting, or edge lifting. Focus inspection on the bonding quality at the four corners and edge areas of the modules. Any anomalies found should be promptly recorded and scheduled for repair.
2. Clamp/Fixture Fixing Method: At each inspection, the firmness of clamps and fixtures and the tightness of bolts must be checked. At the same time, the safety status of the building's relevant supporting structures must be examined. For M8 bolts used for clamp fastening, the tightening torque should be maintained within the range of 15~20 N·m.

Note: ZKFN SOLAR lightweight rigid modules can be walked on for maintenance under specific conditions without causing damage to the modules, resolving the access challenges in lightweight module O&M. For specific walk-on conditions and requirements, please refer to the ZKFN SOLAR SolarPega & SolarPegaF Series PV Module Installation Manual.

3.1.3 Electrical Safety Inspection

1. Focus on inspecting the connection sealing integrity and fastening of PV connectors, and investigate whether DC cables show signs of damage, aging, compression, or tension.

2. Verify the specification and model consistency of PV connectors. If the PV connectors used do not match the original connectors of the PV modules in specification or model, this can easily cause excessive interface fit clearance and seal structure failure, allowing external moisture and dust to invade the connector cavity, causing internal pin oxidation and corrosion, increased contact resistance, leading to abnormal connector heating, arc burn-through, and posing serious safety hazards.

Warning: Throughout the DC side of the entire PV system — from the module factory-installed output cables, field-fabricated jumpers (string extension cables), to the input terminals of combiner boxes and inverters — at any position where plug connections are required, it must be ensured that the male and female connectors originate from the same manufacturer and belong to the same product model series.

3.1.4 Hot Spot Prevention

Conduct infrared thermal imaging inspections on a periodic basis. For minor hot spots (temperature difference < 20°C), perform tracking monitoring and record the trend of change. Modules with severe high-temperature hot spots (temperature difference ≥ 20°C) must be immediately taken out of service and scheduled for replacement. Eliminate module operation with faults, prevent high-temperature fire risks, and ensure safe and stable power generation of the array.

3.1.5 Module Disassembly Prohibition

PV modules are hermetically integrated electrical equipment, and on-site disassembly poses multiple uncontrollable risks. It is strictly prohibited for any personnel to disassemble module face panels, junction boxes, backsheets, internal cells, or other components at the O&M site or during repair processes. Unauthorized removal of the module's factory-installed sealing structures and electrical connection points is not permitted.

3.2 Inspection Frequency and Items

3.2.1 Monthly Inspection Items

A comprehensive inspection of the PV system shall be conducted at least once per month by trained professional O&M personnel. During operations, inspection personnel must wear rubber-insulated gloves and insulated boots at all times. Monthly inspections shall include the following items:

- ✧ Module Surface Cleanliness Check: Visually inspect the module light-receiving surface for dust, bird droppings, oil stains, and other contaminants; determine whether cleaning operations need to be scheduled
- ✧ Module Appearance Integrity Check: Inspect modules one by one for cracks, breakage, scratches, deformation, discoloration, delamination, bubbles, and other anomalies on the module surface
- ✧ Shading Object Inspection: Check for new shading sources on and around the module surfaces (tree growth, new structures, bird dropping accumulation, etc.)
- ✧ Junction Box and Connector Inspection: Check whether junction boxes are secure, box covers are tightly closed, connectors are fully plugged in, and whether there are any signs of arc burn marks
- ✧ Cable and Wiring Inspection: Check whether inter-module connecting cables are loose, aged, or damaged; whether cable tie-downs are in good condition; and whether cable routing is compliant

- Mounting Structure Inspection: For the adhesive method, check the bonding condition of modules (adhesive opening, debonding, corner lifting); for the clamp method, check clamp/fixture tightness
- Monitoring Data Verification: Verify through the monitoring system whether string current, voltage, and power data are within normal ranges; flag abnormal strings

3.2.2 Additional Quarterly Inspection Items

In addition to completing all monthly inspection items, the following specialized inspections shall be added each quarter:

- Comprehensive Infrared Thermal Imaging Scan: Use an infrared thermal imaging camera to perform hot spot scanning on all modules block by block, recording temperature anomaly points
- Array Fuse and Protection Device Inspection: Check whether DC-side fuses, circuit breakers, and disconnect switches are functioning normally
- Drainage System Inspection: Check whether roof drainage gutters and downspouts are unobstructed, and whether there are water accumulation hazards around the modules
- Lightning Protection and Grounding System Inspection: Check whether grounding down-conductor connections are secure and whether grounding resistance values are within the specified range
- Connector Torque Spot Check: Conduct fastening re-inspection of at least 10% of connectors to ensure there is no loosening

3.2.3 Additional Annual Inspection Items

In addition to completing all monthly and quarterly inspection items, a comprehensive in-depth inspection shall be conducted once per year:

- IV Curve Testing: Use an IV curve tracer to perform power characteristic testing on each string or at least 30% of modules, evaluating the deviation between actual power generation performance and nominal values
- EL Inspection (Electroluminescence Imaging): Perform EL inspection on modules with abnormal power degradation to detect internal defects such as cell micro-cracks, broken grid fingers, and cold soldering
- Torque Re-inspection of All Electrical Connection Points: Perform fastening torque re-inspection of all DC-side electrical connection points (including connectors, terminals, and combiner box terminals)
- Roof Support Structure Safety Assessment: Conduct a comprehensive safety inspection of the roof load-bearing structure, mounting brackets, and anchor points, assessing for rust, deformation, and loosening
- Insulation Resistance Testing: Use an insulation resistance tester (DC 500V/1000V recommended) to measure string-to-ground insulation resistance, confirming it meets the relevant standard specified values
- Issue Annual O&M Report: Compile the year's inspection data, fault handling records, and performance degradation trends to produce the Annual PV Power Station O&M Analysis Report

3.3 Special Inspections

Special inspections must be organized immediately after extreme weather events or special operating conditions:

- ✧ After Thunderstorm Weather: Use a thermal imaging camera to check whether junction box temperatures of modules in lightning strike risk areas are abnormally elevated; check whether lightning protection devices have activated
- ✧ After High Wind Weather: Check whether module clamps and fixtures have come off or loosened; whether modules have been flipped or displaced by wind; and whether the roof waterproofing layer is intact
- ✧ After Hail/Snow Weather: Inspect modules block by block for cracks or breakage caused by hail impact; check for module deformation caused by snow load
- ✧ After Sandstorm Weather: Check whether there are sand impact marks on module surfaces; promptly arrange cleaning operations to remove accumulated dust from the surface

4. PV Module Cleaning

4.1 Determining Cleaning Frequency and Timing

1. Routine Cleaning Frequency: In general, modules should be cleaned at least once per month to maintain surface cleanliness. In areas with severe dust (within a 50-meter radius), such as cement plants, mining areas, and along dusty roads, cleaning frequency should be increased to at least once every half month.
2. Trigger-Based Cleaning Conditions: When the power station's generation output drops by more than 5% from normal levels, and equipment faults and meteorological factors have been ruled out, the modules should be cleaned. Cleaning should also be scheduled when any of the following conditions are met:
   - ◆ Visual inspection shows the module surface is noticeably soiled with a visible dust layer
   - ◆ Comparison of power generation between cleaned strings and strings to be cleaned at the same time shows a deviation ≥ 4%
   - ◆ The PV array power output falls below 85% of the initial state (output at the conclusion of the last cleaning)
3. Optimal Cleaning Time Window: Cleaning operations should be performed when irradiance is below 200 W/m². Early morning, late afternoon, or overcast days are recommended. Cleaning PV modules under weather conditions with wind force greater than 4, heavy rain, or heavy snow is strictly prohibited.

4.2 Cleaning Water Quality Requirements

Cleaning water must meet the following standards to avoid scale formation or corrosion on the module surface:

- Total Hardness (as $CaCO_3$): ≤ 200 mg/L
- Total Dissolved Solids (TDS): ≤ 500 mg/L
- pH Value: 6.5 ~ 8.5
- Suspended Solids: ≤ 50 mg/L
- Chlorides (as Cl^-): ≤ 250 mg/L

Note: Where conditions permit, softened water or deionized water should be used preferentially for cleaning, to prevent from the source the formation of difficult-to-remove scale deposits on the module surface.

4.3 Standard Cleaning Procedure

Step 1: Preparation

- Cleaning personnel shall wear complete personal protective equipment including insulated gloves, insulated boots, safety helmet, and safety harness
- Check that cleaning tools (soft cloth, soft roller, clean water bucket, neutral detergent, etc.) are complete and clean
- Confirm that warning signs have been posted in the cleaning area and that unauthorized personnel are not permitted to enter the work zone
- Verify that meteorological conditions meet cleaning operation requirements (no rain or snow, wind speed below Force 4, irradiance below 200 W/m²)

Step 2: Initial Rinse

- Rinse the module surface with clean water from top to bottom to remove loose dust and debris
- Avoid significant temperature differences between the cleaning water and the module surface temperature (temperature difference is recommended not to exceed 10°C) to prevent thermal shock damage to the modules
- It is strictly prohibited to use a high-pressure water jet at close range aimed at the junction box seams and connectors for flushing

Step 3: Deep Cleaning

- • For general soiling, gently wipe in a single direction using a soft cloth or soft roller dampened with clean water; avoid repeated back-and-forth rubbing
- • When stubborn adherents such as oil stains are present on the module surface, use a non-abrasive neutral liquid detergent (pH 6.0~8.0) to assist cleaning
- • It is prohibited to use organic solvents containing acidic or alkaline components to clean modules
- • It is prohibited to use hard tools such as steel wire brushes, steel wool, or metal scrapers to wipe the module surface
- • It is prohibited to use steam cleaners or high-temperature water jets
- • It is prohibited to immerse the entire module in water

Step 4: Rinse and Dry

- • Thoroughly rinse the module surface with ample clean water to ensure no detergent residue remains
- • Use a clean soft cloth (microfiber cloth recommended) to dry residual water droplets from the module surface; avoid natural air-drying which may leave water spot stains
- • The back side of the module generally does not require cleaning; if back-side cleaning is necessary, extra care must be taken to prevent cleaning solution from penetrating into the module interior or the junction box sealing surfaces

Step 5: Cleaning Effectiveness Verification

- • A representative string with the most severe soiling may be selected first for cleaning as a reference
- • If the power improvement after cleaning is less than 5%, it is generally unnecessary to perform a full array-wide cleaning under current conditions
- • The above verification should be conducted under stable irradiance conditions (clear weather, stable irradiance, no cloud cover) to ensure the validity of the comparison data

4.4 Post-Cleaning Inspection Requirements

4.4.1 Visual Inspection

- ✧ • The overall appearance of the modules should be visually clean and bright, free of residual stains and water marks
- ✧ • Conduct spot checks for residual dust accumulation on the module surface
- ✧ • Confirm that there are no new scratch marks on the module surface
- ✧ • Confirm that there is no human-caused cracking or damage to the module surface

4.4.2 Structural Inspection

- ✧ • Check whether cleaned modules show any tilting or bending
- ✧ • Check whether module terminals show any signs of detachment or loosening
- ✧ • Check whether connectors remain dry and clean, and whether sealing rings are intact

4.4.3 Records and Filing

Complete the PV Module Cleaning Record, including: cleaning date, cleaning personnel, cleaning scope (string numbers), cleaning method, water consumption, and pre/post-cleaning string power comparison data, etc.

5. Common Fault Diagnosis and Troubleshooting

5.1 Abnormal Module Power Degradation

Fault Symptoms

Module output power is significantly lower than rated power, and the power degradation rate exceeds the normal range (first-year degradation > 1%, annual degradation from year 2 to year 30 > 0.4%), or unexpected rapid power decline occurs within a short period.

Fault Cause Analysis

- ✧ Modules operating long-term in high-temperature, high-humidity environments, leading to accelerated aging of cells and encapsulation materials
- ✧ Long-term uncleaned dust and dirt accumulation on the module surface, resulting in continuous decline of light transmittance
- ✧ Internal cell micro-cracks and broken grid fingers within the module, affecting the effective collection of photo-generated current
- ✧ Bypass diode failure within the junction box (short-circuit or open-circuit failure), causing partial cell strings within the module to cease operation
- ✧ Persistent localized shading on the module surface, triggering long-term hot spot effects causing permanent cell degradation
- ✧ Poor connector contact or cable aging, resulting in abnormal increase of series resistance

Diagnosis and Troubleshooting Methods

- ✧ Power Testing: Use a professional IV curve tracer or PV module power tester to measure the actual output power of the module, confirming the degree of power degradation and the abnormal IV curve pattern
- ✧ Visual Inspection: Carefully inspect the module surface for dust, dirt, scratches, cracks, etc.; check whether the junction box is intact and free from bulging or deformation
- ✧ Thermal Imaging Inspection: Use an infrared thermal imaging camera to detect whether hot spot effects and abnormal heating points exist on the module

- ✧ EL Inspection: Conduct electroluminescence (EL) imaging inspection on modules suspected of having internal defects to confirm the presence of micro-defects such as micro-cracks, broken grid fingers, and cold soldering
- ✧ If caused by surface dust/dirt accumulation → Arrange cleaning promptly
- ✧ If caused by localized shading → Remove the shading source and optimize the module's surrounding environment
- ✧ If the junction box internal diode is damaged → Replace with the same model junction box (must be performed by ZKFN SOLAR authorized personnel)
- ✧ If the module has severe aging (power degradation exceeding 20%) or irreversible internal defects → Replace the module
- ✧ If the module is still within the warranty period and confirmed to be a product quality issue → Submit an after-sales service request to ZKFN SOLAR in accordance with warranty procedures

5.2 Module Hot Spot Effect

Fault Symptoms

Infrared thermal imaging inspection reveals localized areas of the module with significantly higher temperatures than surrounding normal areas (temperature difference ≥ 20°C). Severe hot spots can cause discoloration and bubbling of module surface encapsulation materials, backsheet burn-through, junction box melting and deformation, and in extreme cases may trigger open flames.

Fault Cause Analysis

- ✧ Localized shading objects present on the module surface (leaves, bird droppings, dust clumps, building shadows, etc.); shaded cells transition from power generation units to power-consuming loads, consuming the electrical energy generated by adjacent normal cells and forming localized high temperatures
- ✧ Performance degradation of individual cells within the module (efficiency decline, increased series resistance), creating electrical mismatch with other normal cells in the same string
- ✧ Cells exhibiting micro-defects such as micro-cracks and broken grid fingers, where obstructed local current flow leads to concentrated heating
- ✧ Bypass diode failure, unable to bypass and protect the shaded cell string when shading occurs

Treatment Measures

Immediate Treatment: Immediately remove shading objects from the module surface; de-energize and isolate modules with severe hot spots to prevent fault escalation.

Inspection and Assessment: Use an infrared thermal imaging camera to precisely determine the location and temperature distribution of hot spots; perform EL inspection on hot-spot-affected modules to assess the degree of internal cell damage.

Graded Disposition:

- ✧ Minor hot spots (temperature difference < 20°C) with no visible internal damage → Continue tracking and monitoring after removing shading objects; add to the priority observation list for the next inspection
- ✧ Moderate hot spots (temperature difference 20 ~ 40°C) → Recommend developing a replacement plan and completing replacement during the next scheduled downtime

- ✧ Severe hot spots (temperature difference ≥ 40°C) or modules already showing visible damage on appearance → Must be immediately taken out of service and replaced

Preventive Measures

- ✧ During the module array design and installation phase, layouts should be rationally planned to avoid inter-module shading
- ✧ Periodically clear vegetation and debris around modules that could form shading sources
- ✧ Ensure module bypass diode functionality remains intact; periodically verify indirectly through IV curve testing
- ✧ Conduct comprehensive infrared thermal imaging inspections on a quarterly basis, establish a module temperature baseline archive, and promptly identify temperature anomaly trends

5.3 Module Wiring and Connector Faults

Fault Symptoms

Unstable or completely absent module output voltage and current; abnormally elevated temperatures at terminals and connectors (hot to the touch or hot spots visible in infrared thermography); oxidation discoloration and arc burn marks appearing on terminal surfaces; in severe cases, melting and deformation of connector plastic housings with a burnt odor.

Fault Cause Analysis

- ✧ Connectors not fully plugged into position, resulting in increased contact resistance and localized heating
- ✧ Connector seal failure (sealing ring aging, damage, or detachment), with moisture and dust intrusion causing pin oxidation and corrosion
- ✧ Male and female connectors originating from different manufacturers or different model series, resulting in large interface fit tolerances and unreliable contact
- ✧ Output cables with insulation layer aging, cracking, and damage due to long-term exposure, causing electrical leakage or short circuits
- ✧ Wiring errors (reversed positive and negative polarity) or incorrect string wiring topology
- ✧ Connectors under prolonged cable tension, causing internal pin loosening

Troubleshooting Procedure

- ✧ Safe De-energization: First disconnect the corresponding combiner box and inverter power supply, perform de-energization verification (verify using a multimeter), and hang "Do Not Close" warning signs
- ✧ Fault Location: Use a multimeter to sequentially test continuity, voltage, and contact resistance values at each terminal, locating the fault point
- ✧ Loose Terminal → Re-tighten to specified torque using specialized tools (exercise appropriate force to avoid damage from over-tightening)
- ✧ Terminal Oxidation/Corrosion → Cut off the damaged section and replace with a new connector of the same model and specification
- ✧ Connector Model Mismatch → Replace all connectors with ZKFN SOLAR-certified matching models
- ✧ Cable Damage → Replace with PV-specific DC cable of the same specification, ensuring wire gauge and voltage rating match the original
- ✧ Wiring Error → Rewire according to the correct positive/negative polarity markings and string wiring diagram

- ✧ Restoration and Verification: After completing wiring, restore power, measure string open-circuit voltage, short-circuit current, and operating current, confirming the fault has been eliminated and parameters are normal

5.4 Inverter-Side and String-Level Fault Diagnosis

Fault Symptoms

Monitoring system shows persistently low or zero output power for a particular string; inverter reports insulation resistance too low fault, DC over-voltage/under-voltage alarms; string current significantly deviates from the average level of other strings in the same array.

Diagnostic Steps

- ✧ Step 1: Identify the fault string number and corresponding physical location through the monitoring platform
- ✧ Step 2: Under safe de-energized conditions, measure the open-circuit voltage (Voc) of the string and compare with normal strings in the same array. If Voc is significantly lower, this indicates module short circuit, bypass diode short circuit, or severe module damage within the string
- ✧ Step 3: Measure the string short-circuit current (Isc). If Isc is significantly lower, there may be severe module dust accumulation, shading, aging, or poor connector contact
- ✧ Step 4: Measure the string segment by segment, progressively narrowing the fault range until the specific problematic module is located
- ✧ Step 5: Perform further diagnostics such as IV curve testing and EL inspection on the identified problematic module, determine the fault type, and take corresponding treatment measures

6. Module Repair and Replacement

6.1 General Requirements for Module Replacement

1. Risk Identification and Mitigation: Before replacement operations, potential risks during the operation process must be comprehensively identified, including but not limited to: personnel lacerations from tool handling, falls from height (for rooftop or elevated work), electric shock hazards during circuit disconnection/restoration, and debris splashing during old module removal, etc. Specific mitigation measures must be developed for each risk.
2. Pre-Work Safety Briefing: A "Pre-Work Safety Briefing" must be conducted before each replacement operation. The work supervisor shall explain the day's work content, specific task assignments, safety precautions, and emergency response procedures to all participating personnel. Written records shall be made and signed by all personnel before work may commence.
3. New Module Verification: Before replacement, each new module must be individually inspected for appearance (confirming no surface scratches, cracks, deformation, and that terminals are intact without defects). The module model, rated power, electrical parameters, and other nameplate information must be checked against the old module for consistency, ensuring electrical compatibility between old and new modules before they can be put into service.
4. Professional Conduct: It is prohibited to use excessive force to pry, strike, or forcibly bend modules, to avoid causing module breakage or personnel injury. During the removal process, care must be taken to protect adjacent module surfaces and electrical connections from damage.

5. Waste Disposal: Waste modules, glass fragments, damaged accessories, and other items generated from replacement must be collected separately and stored centrally. Damaged modules shall be professionally disposed of in accordance with hazardous waste management requirements. Random disposal or mixing with ordinary construction waste is prohibited.

6.2 Replacement Procedure for Adhesive-Mounted Modules

Applicable to SolarPega / SolarPegaL (frameless) modules. The specific replacement steps are as follows:

1. Plan Preparation: Before module replacement, a Lightweight Rigid Module Replacement Implementation Plan shall be prepared, defining the operational process, personnel assignments, safety measures, and quality acceptance criteria
2. De-energization Confirmation: Before commencing work, the corresponding combiner box and inverter power supply for the module must be disconnected. A "Do Not Close, Personnel at Work" warning sign shall be hung at the disconnection point. A certified electrician shall use a multimeter to verify the absence of voltage on both sides of the disconnection point before subsequent work may begin
3. Module Covering: Completely cover the front surface of the module to be replaced with opaque material (such as black light-blocking cloth or thick cardboard) to block light and prevent the module from generating high voltage
4. Electrical Disconnection: Use specialized unlocking tools to separate the module's positive and negative connectors; make cable markings
5. Old Module Removal: Use tools such as utility knives and scrapers to carefully cut the structural adhesive along the bonding interface, gradually separating the old module from the roof substrate. During operation, control force and angle to avoid damaging surrounding modules and the roof waterproofing layer
6. Substrate Cleaning: Thoroughly remove residual structural adhesive and debris from the roof substrate, ensuring the bonding surface is dry, clean, and flat. If necessary, perform sanding treatment on the substrate to restore surface roughness
7. New Module Installation: Strictly follow the standardized procedures in the ZKFN SOLAR SolarPega & SolarPegaF Series PV Module Installation Manual for adhesive application, module placement, roller pressing, and positioning
8. Curing Protection: During the structural adhesive curing period (24 hours at 25°C~40°C ambient temperature, 48 hours at 10°C~25°C, 72 hours at 0°C~10°C), it is strictly prohibited to apply any disturbance to the module, including but not limited to moving the module, connecting cables, or performing other work while standing on the module. Protective barriers and warning signs shall be installed in the replacement area
9. Electrical Connections: After the structural adhesive has fully cured, re-connect the connectors according to the marked correct positive/negative polarity correspondence, ensuring they are plugged in fully and an audible "click" locking sound is heard
10. Power-On Testing: Remove the covering material, close the switch to restore power supply. Use a multimeter or IV curve tracer to measure the output parameters of the new module, confirming compatibility with other modules in the same string and normal operation
11. Records and Filing: Record in detail the replacement date, replacement reason, old module serial number and fault type, new module serial number and initial test data, operating personnel information, etc.; update the power station O&M archive

6.3 Replacement Procedure for Clamp/Fixture-Mounted Modules

Applicable to SolarPegaF / SolarPegaFL (with back-frame) modules. The specific replacement steps are as follows:

1. Plan Preparation: Before module replacement, a Clamp-Fixed Lightweight Rigid Module Replacement Implementation Plan shall be prepared, defining the operational process and safety measures
2. De-energization Confirmation: Same as Requirement 2 of the Adhesive-Mount Replacement Procedure
3. Module Covering: Same as Requirement 3 of the Adhesive-Mount Replacement Procedure
4. Electrical Disconnection: Same as Requirement 4 of the Adhesive-Mount Replacement Procedure
5. Old Module Removal: Use a torque wrench to loosen and remove the clamp fastening bolts to the specified torque, remove the clamps in sequence, and carefully move the old module out from the installation surface. During the operation, be careful to avoid colliding with surrounding modules
6. Installation Surface Inspection: Clean debris and rust from the installation surface; check whether clamps/brackets show deformation, rust, or looseness. If anomalies are found, the damaged accessories must first be repaired or replaced before proceeding to the next step
7. New Module Installation: Position the new module at the designated location, adjusting the module position to ensure uniform peripheral gaps. Install clamps in sequence, uniformly tightening M8 bolts to a torque of 15~20 N·m. Note that clamps must press on the designated load-bearing area of the module back-frame and must not press on the effective cell area above
8. Electrical Connections: Same as Requirement 9 of the Adhesive-Mount Replacement Procedure
9. Power-On Testing: Same as Requirement 10 of the Adhesive-Mount Replacement Procedure
10. Records and Filing: Same as Requirement 11 of the Adhesive-Mount Replacement Procedure

6.4 System Verification After Module Replacement

After completing module replacement, in addition to individual testing of the new module, the overall performance of the affected string shall also be verified:

- ✧ Measure the string open-circuit voltage (Voc) and short-circuit current (Isc), comparing with the string design values and normal strings in the same array
- ✧ Monitor the string operating current to confirm good current matching between the new module and existing modules in the string
- ✧ Observe power generation data over at least one full sunshine day to confirm that string power has recovered to normal levels
- ✧ If conditions permit, perform infrared thermal imaging scanning of the newly replaced module area to confirm the absence of abnormal heating points

7. Emergency Response Measures

7.1 Emergency Response to Module Electrical Leakage

Upon discovery of a module electrical leakage alarm or suspected leakage situation, O&M personnel must immediately execute the following handling procedures:

- • Personnel Emergency Evacuation: Immediately move away from the leakage area; do not touch the leaking module and its surrounding metal components; simultaneously prevent other personnel from entering
- Safe De-energization: Certified professionals wearing insulating gloves rated for the appropriate voltage level shall use an insulated operating rod to disconnect the corresponding combiner box and inverter power supply, and hang warning signs
- Fault Detection: Use an insulation resistance tester (DC 500V/1000V) to measure the insulation resistance to ground of the leaking string segment by segment, using the sectional elimination method to locate the leaking module
- Cause Investigation: Inspect the leaking module for conditions such as water ingress in the junction box, connector seal failure, cable insulation damage, and backsheet penetration damage
- Repair Disposition: Replace the faulty module, damaged cables, or connectors based on the cause of leakage. After repair is complete, re-test insulation resistance to confirm restoration to acceptable levels
- Power Restoration: Only after all tests are passed may warning signs be removed and power be restored. After power restoration, continuous monitoring shall be conducted for at least 1 hour to confirm the absence of anomalies

7.2 Emergency Response to Module Fire

ZKFN SOLAR SolarPega series modules have passed UL790 Class C standard testing and certification for fire performance, demonstrating good fire resistance. If a module fire incident occurs at the O&M site, the following procedures shall be followed:

- Immediately disconnect all DC-side and AC-side power supplies to the fire-affected PV system
- If the fire is small and safe conditions permit, use a dry powder extinguisher or carbon dioxide extinguisher to suppress the fire at the source. It is strictly prohibited to use water or foam extinguishers directly on modules and energized electrical equipment
- If the fire is too large to control independently, immediately call 119 to report the fire, clearly communicating key information such as "PV power station fire, DC high voltage hazard," and organize all personnel to evacuate to a safe area
- After the fire is extinguished, conduct a systematic investigation of the fire cause, assess the damage level of each module and electrical equipment, and prepare the Fire Incident Analysis and Restoration Plan
- Only after confirming that all safety hazards have been eliminated (including structural safety, electrical insulation, and module integrity) may the power station be gradually restored to operation according to the restoration plan

7.3 Emergency Response to Extreme Weather

7.3.1 Rainstorm/Flooding

- After a rainstorm warning is issued, inspect and clear debris from roof drainage gutters and downspouts to ensure the drainage system is unobstructed
- Provide waterproof protection or relocate inverters, combiner boxes, monitoring hosts, and other indoor or low-lying equipment to a safe elevation
- During the rainstorm, cease all outdoor O&M operations. If flooding occurs at the power station, immediately disconnect all power supplies remotely or on-site

- • After floodwaters recede, perform drying treatment, cleaning, and insulation testing on all water-affected modules, cables, connectors, and electrical equipment. Only after confirming the absence of safety hazards may operations be gradually restored

7.3.2 High Wind/Typhoon

- After a high wind warning is issued, comprehensively inspect the fastening condition of module clamps and fixtures, and reinforce any loose bolts
- Clear loose objects around the module array that could be easily picked up by wind (advertising boards, temporary covers, loose materials, etc.)
- During the typhoon, shut down the power station power supply and evacuate all personnel to a safe area
- After the wind event, comprehensively inspect modules for displacement, detachment, deformation, and damage; inspect whether mounting brackets and roof structures are intact. Repair damaged areas and only restart the power station after passing comprehensive inspection

7.3.3 Blizzard/Low Temperature

- During a blizzard, periodically use a soft snow pusher (silicone or rubber material) to clear accumulated snow from module surfaces. During operation, be careful to avoid the tool colliding with junction boxes and connectors
- In low-temperature environments, check whether connectors and terminals show signs of icing. If icing has occurred, wait for natural thawing and complete drying before performing operations
- When clearing snow, it is strictly prohibited to step on modules (It is allowed to step on it when the stepping installation conditions are met. Please refer to the installation operation instructions for details), to avoid causing internal cell micro-cracks or damage to the encapsulation structure
- After snow events, inspect module surfaces for cracks or deformation caused by snow load or freeze-thaw cycles; damaged modules should be promptly scheduled for replacement

7.4 Emergency Response to Lightning Strikes

The thunderstorm season is a high-risk period for PV power stations suffering lightning strikes. If the monitoring system shows widespread module communication interruption, inverter tripping, or on-site inspection reveals obvious lightning strike marks on modules (such as junction box puncture, module surface arc burn spots), the following handling procedures shall be immediately initiated:

- Immediately disconnect all power supplies to the power station; personnel shall promptly evacuate to a safe indoor area
- After the thunderstorm passes, comprehensively inspect the lightning protection and grounding system: check grounding down-conductors for breakage or fusing; measure whether grounding resistance still meets design requirements (generally required to be ≤ 4Ω)
- Inspect the appearance of modules block by block; use an infrared thermal imaging camera to scan for abnormal heating points
- Measure insulation resistance and IV characteristics of strings affected by lightning strikes; replace modules that have been punctured or have severely degraded performance
- Inspect whether surge protective devices (SPDs) inside inverters and combiner boxes have activated or been damaged; if damaged, they must be promptly replaced

8. O&M Records and Archive Management

8.1 O&M Records Management System

The completeness and accuracy of O&M records form the foundation for power station asset management, warranty claims, performance assessment, and fault tracing. It is recommended to establish archive management principles of "full lifecycle coverage, dual-track electronic and paper systems, equal emphasis on safety and utilization." Through standardized record collection and regulated archive management, achieve O&M process traceability, problem locatability, and decision supportability, forming a closed management loop of "Record – Archive – Utilize – Optimize."

O&M records shall cover the following categories:

- Inspection Records: Record inspection date, inspection personnel, inspection scope (strings/areas), inspection results (module appearance condition, operating parameter data, problems identified and on-site handling), tracking of unresolved issues
- Cleaning Records: Record cleaning date, cleaning personnel, cleaning scope, cleaning method, water consumption and quality, representative string power comparison data before and after cleaning
- Fault Handling Records: Record fault occurrence date and time, fault module serial number and location, fault symptom description, fault cause analysis, specific handling methods and steps, handling results, repair personnel signature, list of materials and spare parts used for repair
- Module Replacement Records: Record replacement date, information on replaced old module (serial number, model, years in service, fault type), information on new module (serial number, model, initial electrical performance test data), replacement operating personnel
- Emergency Response Records: Record the time and location of the emergency incident, incident type and severity, specific emergency response measures and execution process, response results and subsequent impact assessment, personnel involved in the response
- Specialized Testing Records: Record the date, scope, method, raw data, and analysis conclusions of specialized tests such as IV curve testing, EL inspection, infrared thermal imaging scanning, and insulation resistance testing

8.2 Archive Classification and Filing

Archive management is recommended to adopt a four-level classification system of "Primary Classification – Secondary Classification – File Group – Document":

- Basic Archive Category: Includes module factory documentation (certificate of conformity, factory test report, technical parameter list), procurement contracts, warranty agreements, system as-built drawings, completion acceptance reports, etc. File groups are organized by "Project – Equipment Type"
- O&M Process Archive Category: Compiles the various O&M records mentioned above, with file groups organized by "Year – O&M Type – Area." Among these, inspection records shall be summarized monthly and bound accordingly; fault handling records shall be separately established as "one case, one file," including supporting materials such as test reports, pre- and post-repair comparison photographs
- Performance Monitoring Archive Category: Separately stores professional testing data such as IV curve tests, EL inspections, and hot spot scans. Establish a "Module-Specific Performance Ledger" indexed by module serial number, recording key performance data at

each testing node throughout the full lifecycle, and annually compile the Module Performance Degradation Analysis Report

- ✧ Compliance Management Archive Category: Includes copies of O&M personnel qualification certificates, testing instrument calibration certificates, waste module recycling and disposal certificates, industry regulatory inspection records, safety training records, etc., ensuring that O&M activities are fully compliant and traceable throughout the entire process

8.3 Annual O&M Report

A comprehensive Annual PV Power Station O&M Analysis Report shall be prepared and submitted each year. The report shall contain at least the following content:

- ✧ Annual power generation statistics and comparative analysis against design values and the same period of the previous year
- ✧ Annual inspection and cleaning operation summary statistics (number of inspections, number of cleanings, number and type distribution of problems identified and resolved)
- ✧ Module performance degradation trend analysis (based on IV curve and EL inspection data)
- ✧ Fault statistical analysis (fault type distribution, fault rate, mean time to repair, impact assessment on power generation)
- ✧ Annual O&M cost statistics, and O&M plan and budget recommendations for the following year
- ✧ Key focus areas and improvement recommendations for the following year

9. Appendix

9.1 Frequently Asked Questions (FAQ)

Q1: What is the recommended maintenance interval for ZKFN SOLAR SolarPega series lightweight rigid PV modules? What are the main items to check?

A: It is recommended to conduct comprehensive inspections at least once per month, checking the operational performance of all modules, electrical connection safety and reliability, mounting structure stability, and module surface cleanliness. Main inspection items include: module appearance integrity, electrical connection firmness, junction box and connector integrity, module surface cleanliness and shading conditions, mounting support structure stability, lightning protection and grounding system integrity, monitoring system operational status, and string power output normality. It is also recommended to clean the modules at least once per month to ensure PV power generation efficiency.

Q2: If a small amount of dust appears on the module surface but hasn't reached the cleaning trigger threshold of a 5% power drop, is cleaning necessary?

A: If the dust layer is thin and rainfall is forecasted in the short term, cleaning can be postponed while continuously monitoring power trends through the monitoring system. However, if local air pollution is severe, the dust contains sticky substances prone to caking, or no effective precipitation is forecasted within the next week, it is recommended to schedule cleaning in advance to prevent long-term dust accumulation from hardening into a crust, which would increase subsequent cleaning difficulty and continuously affect light transmittance.

Q3: If modules ice over in winter, can hot water be used directly to melt the ice?

A: It is strictly prohibited to use hot water for direct rinsing or pouring onto ice-covered modules. Severe temperature differentials between cold and hot will cause thermal shock stress to the glass panel and encapsulation materials, potentially leading to module glass

breakage or encapsulation layer failure. It is recommended to wait for ambient temperature to rise to allow the ice to melt naturally, or to use a silicone/plastic dedicated de-icing scraper (metal tools are strictly prohibited) to gently remove surface ice. After the ice has completely melted and the module surface is dry, inspect the module for signs of water ingress or damage.

Q4: If module power degradation exceeds the normal range but the module is still within the warranty period, how do I apply for after-sales service?

A: First organize the complete O&M archive for the module (including inspection data, IV curve power test reports, fault photographs, EL inspection images, etc.), contact the ZKFN SOLAR after-sales service department, and submit the Warranty Period After-Sales Service Application Form with relevant supporting materials. ZKFN SOLAR will arrange for authorized technical personnel to conduct on-site verification and testing. Upon confirmation that the issue is a product quality problem, corresponding repair or replacement services will be provided in accordance with the warranty policy.

Q5: Can O&M personnel step on modules for cleaning or maintenance?

A: ZKFN SOLAR SolarPega series lightweight rigid modules can be walked on for maintenance under specific conditions without causing damage to the modules. However, walk-on operations must strictly comply with relevant technical conditions and requirements (refer to the Installation Manual for specific conditions), including: walk-on area restrictions, sole material requirements (soft-soled shoes), load distribution measures, etc. Before confirming that conditions are met, directly stepping on the module surface is strictly prohibited.

Q6: How to determine whether a module needs replacement rather than repair?

A: Modules should be directly replaced rather than repaired under any of the following circumstances: ① The module surface shows penetrating cracks or extensive shattering; ② The junction box is severely melted, deformed, or burnt; ③ Infrared thermal imaging shows severe hot spots (temperature difference ≥ 40°C); ④ EL inspection shows extensive cell micro-cracking (crack area exceeds 30% of cell area); ⑤ Module output power has degraded by more than 20% from the nominal value; ⑥ Water ingress inside the module has caused insulation resistance to remain persistently below the standard value and cannot be recovered.

9.2 Common O&M Tools and Instruments Checklist

The following are recommended common tools and testing instruments for PV power station O&M:

- ✓ Digital Multimeter (CAT III 1500V rating) — Measuring DC voltage, current, and continuity
- ✓ Clamp-Type DC Ammeter — Measuring string operating current without breaking the circuit
- ✓ IV Curve Tracer (diagnosing performance degradation) — Measuring the current-voltage characteristic curve of modules/strings
- ✓ Infrared Thermal Imaging Camera — Hot spot detection, connector and terminal heating point investigation
- ✓ Insulation Resistance Tester (DC 500V/1000V) — Measuring string-to-ground insulation resistance
- ✓ EL Inspection Equipment — Detecting internal defects such as cell micro-cracks, broken grid fingers, and cold soldering

- ✓ Torque Wrench (0~30 N·m) — Electrical connection and clamp bolt fastening torque verification
- ✓ MC4 Connector Specialized Disassembly/Assembly Tools — Safe connector separation and mating
- ✓ Grounding Resistance Tester — Periodic testing of lightning protection and grounding systems
- ✓ PV-Specific Cleaning Toolkit (including soft-bristle brush) (soft roller, microfiber cloth, soft water squeegee, etc.)

9.3 Technical Support and Contact Information

Service Hotline: (+86) 400 6768 100 (Office Hours: 8:30-17:30, Beijing Time) (Workdays 8:30 – 17:30)

Technical Support Email: tech-support@zkfnsolar.com

Official Website: www.zkfnsolar.com

Manufacturing Base Address: Building 1, Xinshenglin, Lvhaihui Intelligent Manufacturing Industrial Park, Jining Economic Development Zone, Jining City, Shandong Province

9.4 Manual Revision Notes

This manual is Version A01, released on May 09, 2026. ZKFN SOLAR will periodically revise and improve the manual content based on module technology upgrades, industry standards updates, and user feedback. Revised versions will be published through the official website download center and notified to registered users through email and other channels. Users may obtain the latest version free of charge. If users discover any issues or have suggestions for improvement while using this manual, they may send an email to tech-support@zkfnsolar.com, and we will promptly evaluate and incorporate them into the revision plan.

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