

O&M Manual



Version: 3.0
Date: 14.10.2024
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EXECUTIVE SUMMARY

Thank you for choosing Jinko Solar as your supplier of photovoltaic (PV) modules. To ensure the PV modules are installed correctly, please carefully read and strictly follow the installation and operation instructions manual. The purpose of this Manual is to provide the O&M suggested procedure to all our customers.

This manual is applicable only to the PV modules that are installed, connected and operated in accordance with the installation and operation instructions, hence covered by Jinko's Product Warranty.

IMPORTANT SAFETY RULES

Before accessing any solar power plant and carrying out any visit, inspection, works, maintenance, and any activities alike, please consider that PV modules generate direct current (DC) electrical energy when exposed to sunlight or other light sources. Active parts of the PV modules, including but not limited to, terminals may cause burns, sparks, and result in lethal electric shock. PV modules shall be handled exclusively by authorized personnel adequately trained and fully equipped to access a power plant involving, among others, the risk of an electric shock.

Make sure that you always strictly comply with all health and safety laws and regulations applicable in the territory where the PV Modules are installed. The following are some general recommendations that we wish to share with you, provided such recommendations shall not be regarded as a substitute of the prescriptions of any applicable law or regulation, the compliance with which shall always prevail in all cases:

- Always wear protective head gear, insulating gloves and safety shoes with rubber soles.
- Due to the risk of electrical shock, do not perform any work if the terminals of the PV module are wet. Always use insulated tools and never use wet tools.
- During the operation, do not use sharp tools to wipe the back sheet and the glass. It may cause scratches and damages to the PV module and potentially hinder its operational capability and/or limit your benefit to the Warranty.
- Never disconnect the PV Module connectors under load.
- Do not cut the wires while the module is under load.
- Do not open any fuse switch disconnectors if it is not developed to mitigate the electrical arc.

Should you have any doubt, inquiry, and support request, please do not hesitate to contact the Jinko Technical Team by writing directly to:

cs.eu@jinkosolar.com

GENERAL PREVENTION ACTIONS FOR OPTIMUM DEPLOYMENT

- The working environment shall not exceed the temperature limits from -40°C to 85°C.
- Shading-free installation throughout the year.
- Lighting protection, especially in places with frequent thunder and lightnings.
- When modules are installed at locations with high wind or snow impact, it is needed to guarantee that the mechanical limits (specified in our installation manual) are not exceeded.
- PV modules shall not be installed in hazardous environments with extreme corrosive substances, such as acid rain active chemical gas, which affect their operation life and performance. In case of any doubt please contact Jinko technical service.
- Operation, maintenance, and cleaning procedures shall align with international standards and recommended actions described in this manual.

GENERAL O&M RECOMMENDATIONS

- Always perform installation according to the JKS installation manual.
- Do not cut the plugs off, otherwise you risk losing the warranty.
- Use only the recommended plugs and crimping tools.
- Never walk on the panels.
- Avoid jet washing/high pressure cleaning.
- Perform visual and thermal imaging checks at least once a year.

STANDARD MANTAINANCE OPERATIONS

Description	Remedy/Action
Check for dust/debris on surface of PV module	Wipe/wash clean. No high-pressure water jet. No acid solution.
Check for physical damage to any PV module	Recommend replacement if damage found
Check for loose cable terminations between PV module, PV arrays, etc.	Retighten connection
Check for cable conditions	Replace cable if necessary

Planning, operating, and repairing

For planning or repairing, keep in mind the following:

- Provide elevated pads to prevent flooding of ground-mounted equipment and provide permanent storm-water management system that integrates the surrounding properties.
- Enable third-party inspections and commissioning of original EPC installations to spot operation problems before acceptance (EPRI 2010)¹.
- Conform to the evaluation and quality assurance protocol detailed in the SAPC PV System Installation Best Practice Guide (applicable to residential systems only)².
- Build PV and storage systems following relevant standards, such as IEEE 937 (2007): recommended practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaics Systems.
- Apply IEC 62446 (2009): Grid Connected PV Systems- Min. Requirements for System Documentation, Commissioning Tests and Inspections), which requires documentation of the system, array testing, and whole system performance test. Commissioning is the link between the EPC contractor and the operator.

- Bifacial (Dual Glass and Glass Transparent Backsheet): To be inspected and maintain as standard panels. Additionally, for bifacial modules special care shall be taken to avoid shadowing of the rear, i.e. inadequate wiring and equipment or the structural shading of the mounting system. The transparent backsheet is self-cleaning, however the rear side shadowing shall be monitor as well.
- Smart (MX) panels: Always check the open-circuit voltage (Voc), the lack of 1 cell string means the loss of about approx. 10 Voc, so it is easy to detect.

Repair or replacement of components

Please note: Defective modules and components may only be repaired or replaced by trained and experienced personnel.

- Select alternatives with low level or– maintenance free ,when available (i.e. plastic wire ties would require replacement whereas coated metal ones may not).
- Track performance of used equipment and identify and specify the ones that have low failure rates, and which have the best OEM warranty service; standardize on preferred products to avoid mismatch of parts and expertise in a fleet.
- Make use of network-connected inverters for remote testing, software configurations and/or updates, and remote resets.
- Provide required access to and clearance around equipment for maintenance (EPRI 2010)¹.

Prevention is always better than aftercare!

- Check all results/reports of the data logging.
- Check the performance of the site with your annual inspection.
- If you find electrical data mismatches on string level, examine for the reasons, compare the results with the initial start-up protocol.
- Anything that has changed must be examined.
- Any change/repair must be carefully documented. A proper documentation should include when, whom and what has been done.
- Check the open circuit Voc on string level.
- Check the fuses in the combiner boxes.
- Check all connectors at the inverter entrance.

¹ EPRI 2010: Electric Power Research Institute, "Renewable Energy Technology Guide: 2010", Technical Report 1019760, December 2010.
² A. Walker, T. Keating, and K. Ardani, SAPC Best Practices in PV Operations and Maintenance Version 1.0, Report number: NREL/SR-6A20-63235Affiliation: National Renewable Energy Laboratory's Solar Access to Public Capital, 2015.

- Identify any suspicious string(s).
- Measure the current-voltage (I-V) curves or/and do a FLIR (drone flight) on the panels, cables, connectors.

Safety

- If you inspect a site with an unknown state of health, switch off all DC connectors before you touch anything, to avoid high voltage risks.
- Only experienced well-trained experts should work on PV sites.
- In case of resistance insulation (R iso) problems, a trained person must carry out the inspection and at least one person must supervise in case of an emergency. Follow strictly all safety rules as mentioned in the installation manual.
- Always wear a head protection.
- Wear insulated rubber gloves and safety shoes, resistance at minimum 1000V /1500V DC.
- Use only proper insulated tools to work on panels/cables/connectors etc. (1000/1500 V DC insulated).
- Do not touch frames, backsheet, cables when wet, with failures and /or over temperature.
- If you disconnect strings/panels, be sure not to do this under load.
- If you disconnect single panels, cover the front with an opaque (light blocking) cover.

GENERAL INSPECTION PROCEDURE

- Visual inspection annually or on demand:
 - Checking the annual data, overall performance of the site.
 - A good practice is to check the data recordings/data from inverters.
 - A proper documentation of findings is needed; this includes, among others: pictures, location at the installation site, observations, daytime and environmental conditions.
- Electrical inspection, in combination with the annual visual inspection or on demand.
- Mounting structure.
- Thermographic checks.
- Summarize the results, action to be taken if necessary.

Visual Inspection

Schedule:

- According to the demand. A recommended practice is once a year, and as a minimum practice at least once every three years.
- Must be carried out and protocolated by experienced and trained technical experts.
- Conduct an inspection immediately after severe weather events occur, such as thunderstorms, hail, and high winds.
- Observations should be documented in time and space and supported with photographs, infrared images, among others).

A. Rooftop Installations

As recommended, a "shade-free" installation shall be guaranteed through the whole year. The following pictures show poor maintained roof installations.



Growing plants lead to shadows on the cells: Hot spot risk, loss of performance³



Algae growing in wet conditions destroy the insulation⁴

Avoid installations nearby exhaust chimneys release moisture, ammonia, dust and grease fumes, which can accumulate deposits on the glass surface.

If this installation cannot be avoided, the frequency of cleaning shall be adapted to reduce power reduction due to dust accumulation.



Typical example of delamination caused by algae growth between the frame and the laminate⁵

³ JinkoSolar internal presentation

⁴ JinkoSolar internal presentation

⁵ JinkoSolar internal presentation



Example of risk of accumulation of deposits on the glass surfaces of the panels due to proximity to exhaust stacks⁶

Recommended actions during inspections:

- Check for glass corrosion, debris, etc.
- Check for hotspots

B. Field Installation

- Jinko PV modules should be installed in suitable locations. Do not install the modules in places that could be flooded.
- Be careful when installing the photovoltaic modules particularly at the corners of the racks or trackers.
- The lowest point of the modules height shall be enough to minimize the risks of plants and objects affecting the rear side of the modules.



In case of flat tops with plants, make a regular visual check for debris of vegetation⁷

Recommended actions during inspections:

- Check the rear side of the panels too for backsheet cracking, punctures, etc. Be sure that there is nothing that can scratch or puncture the backsheet (growing plants, parts of the substructure, etc.).
- Check for any damage, done by animals (chewing wires).
- For bifacial PV modules: The installation shall consider the optimization of the height above ground, to reduce non-uniformity of the rear irradiance⁸.
- Too boost bifacial gains and reduce mismatch losses of the rear-side, shading effects of the rear side due to cables, structures, any obstacles or vegetation (also seasonal) shall be avoided.
- Regular maintenance work should be carried out to ensure that variations in the albedo of the soil surface are kept low and consequently the irradiance at the rear and the bifacial gain have less fluctuation. For example, vegetation growth (with albedo 10-25%) should be avoided when trying to keep a sand albedo (22-43%).

C. All Installation

The following pictures represent the typical examples of failures that can be found at your PV installation and should be carefully checked.



Hotspot frontside⁹



Hotspot rear side¹⁰

⁶ JinkoSolar internal presentation

⁷ Download Free Vectors, Clipart Graphics, Vector Art & Design Templates. (n.d.). Retrieved February 01, 2021, from <https://www.vecteezy.com/free-photos/solar-energy>

⁸ Jinko Solar Whitepaper on Swan Bifacial Modules. (n.d.). Retrieved February 1, 2021, from <https://www.pv-tech.org/industry-updates/jinko-solar-whitepaper-on-swain-bifacial-modules>

⁹ Photovoltaik und Waermepumpen Gutachten Sachverständiger Streib. (n.d.). Bilder aus meiner Arbeit als Sachverständiger. Retrieved February 1, 2021, from <http://www.gutachten.streib.de/bilder/index.html>

¹⁰ Sieg, M. (2017, April 19). Schmelzende Rückseitenfolien, kaputte Zellen und Hotspots. Retrieved February 1, 2021, from <https://www.pv-magazine.de/2015/11/04/schmelzende-rckseitenfolien-kaputte-zellen-und-hotspots/>



Broken glass, damage probably caused by impact, for example hail, stones, etc.¹¹



Damage after hail impact¹²

Recommended actions during inspections:

Search for hot spot, broken glasses, cracked backsheet, broken/burnt junction boxes. Inform about the findings and replace the panels, if possible, following the safety rules.

ELECTRICAL INSPECTION

A. Cables

- Check if all cables are fixed. All cables should be away from the roof/clear of the ground.
- No sharp bending, no cutting, etc.
- Cable channels are not filled with water.
- No exposure to UV.
- Protection for all cable entries.



Improper cable installation¹³



Example of improper cable installation¹⁴

B. Connectors

Prevention:

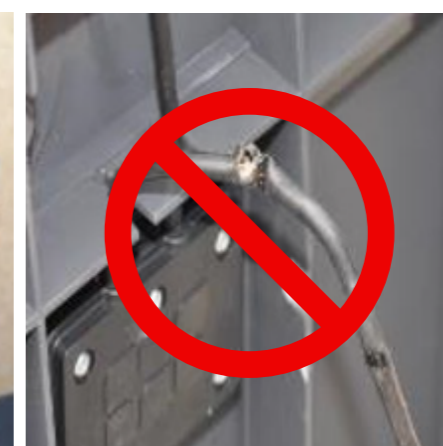
- Connectors shall be kept clean and dry.
- Avoid connecting them if they are found on improper condition such as high humidity or water immersion, extreme dirt, etc. There is a high risk of an electric arc and an electric shock when an improper connection is found.
- Only compatible connectors can be used i.e., from the same supplier and model. Please, ask Jinko if you have doubts about this.

Recommended actions during inspection:

- Visual check.
- Temperature check under load, FLIR image.
- Check for any color change (bleached cable colors).
- Avoid any use of grease, oil etc. at the connectors.
- If in doubt refer to thermography (Infrared, IR) measurement.



Example of improper cable installation¹⁵



Example of improper cable installation¹⁶

¹¹ Photovoltaik und Waermepumpen Gutachten Sachverständiger Streib. (n.d.). Bilder aus meiner Arbeit als Sachverständiger. Retrieved February 1, 2021, from <http://www.gutachten.streib.de/bilder/index.html>

¹² Photovoltaik und Waermepumpen Gutachten Sachverständiger Streib. (n.d.). Bilder aus meiner Arbeit als Sachverständiger. Retrieved February 1, 2021, from <http://www.gutachten.streib.de/bilder/index.html>

¹³ JinkoSolar internal presentation

¹⁴ Dach holzbau. (n.d.). Retrieved February 1, 2021, from <https://www.dach-holzbau.de/>

¹⁵ JinkoSolar Internal Presentation

¹⁶ JinkoSolar Internal Presentation

Recommended actions during inspection:

- A replacement of the connectors, cables etc. that have an insulation problem (safety rules) is recommended. Only original crimping tools and original connectors shall be used (no cross connection is allowed). A professional technician is needed for this purpose. Do not repair defected modules on your own if you do not have the training and experience.
- If needed, use cable tunnels and cable entries to protect the cables, use metal cable clips for fixing, plastic cables are not UV resistant enough.
- Keep all cable out of any water leading surface, in cable tunnels, there must be holes to drain the water.
- For cable replacement, use only the same or bigger diameter. Best choice is 6 mm².

C. Sensors (visual and electrical check)

- All sensors must be well fixed and in place.
- Check the electrical cables and connectors.
- Check that they are properly working.
- Check the cables being fixed to the substructure and not running over cells and modules.

D. Isolation resistance (Riso) and open-circuit voltage (Voc)

The IEC 62446-1:2016¹⁷ along with defining documentation and information needed for grid connection, also describes the commissioning tests and inspection criteria to check the correct and safe operation of systems. There are three categories for testing, which increase according to the complexity of the system. As part of the category 1 tests, insulation resistance tests must ensure electrical safety by showing sufficient insulation between electrically conductive components and the PV panel frame, or between the PV module and the external environment.

Important: It is important to assure a ground connection of the PV modules and the mounting systems. The installation should include a proper connection to an existing lightning protection system. Inadequate insulation can lead to electric shock and other hazards.

Recommended actions during inspection:

- Check Voc on string level, compare the measured values to the initial start up protocol, values should be in a range of + - 10V, if not check the root cause, possible reasons are climatic conditions, such as irradiance or temperature.
- R iso, should be in the allowed range, if lower than 1 MOhm, check the cables, connectors, panel (for delamination, open JB etc.). In this case be very careful not to touch the frames cables etc. if you measure high tension – health/ life risk!
- We recommend doing the R iso check by night.



Electrical device for R iso, Voc, I-V curves:



¹⁷ IEC 62446-1:2016 Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection

¹⁸ JinkoSolar Internal Presentation

¹⁹ JinkoSolar Internal Presentation

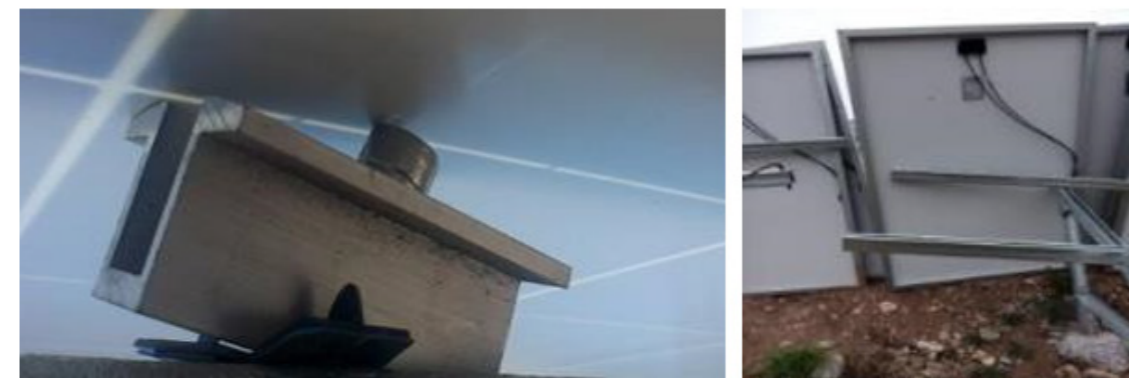


E. Mounting System:

- Through-bolting is preferred to self-tapping screws. Self-tapping screws are more likely to pull out and due to hardened threads and lack of galvanized coating on the threads, they get weaker over time due to corrosion.
- Through-bolting is preferred to clamp in rack hardware. Clamps may have the specified strength in the proper orientation when forces are applied in the proper direction, but relative movement rotation, or vibration of rack parts in a storm can cause them to release. An entire row of modules can fail if one module is lost, and they are held by T-shaped clamps that hold two modules at one point.
- Stainless-steel boxes with thick rubber gaskets and multiple closure attachments stay intact and exclude moisture more effectively than those with one handle-actuated attachments.
- To avoid water infiltration in such scenario and to keep insects out, masthead must be sealed with foam packing.
- Drainage from boxes and conduit runs must be provided in the case of water infiltration.

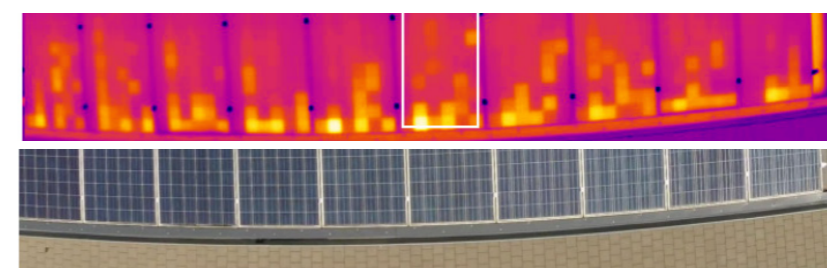
Recommended actions during inspection:

- Check visual for corrosion, fixed clamps, open screws
- Check the grounding panels to aluminum profiles of the substructure
- Check electrical connection to the grounding system (potential)
- Check all fixing points to the roof (retighten with appropriate torque if necessary)
- Check that no part of the system scratches the backsheet
- Check ballast system of the flat roof systems
- Check for all parts are in place
- Check that the system is still positioned as designed and installed

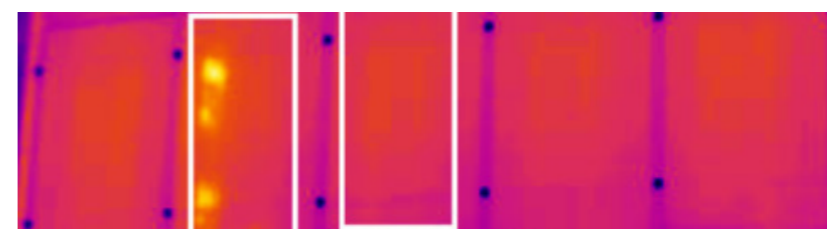


F. Thermographic (FLIR):

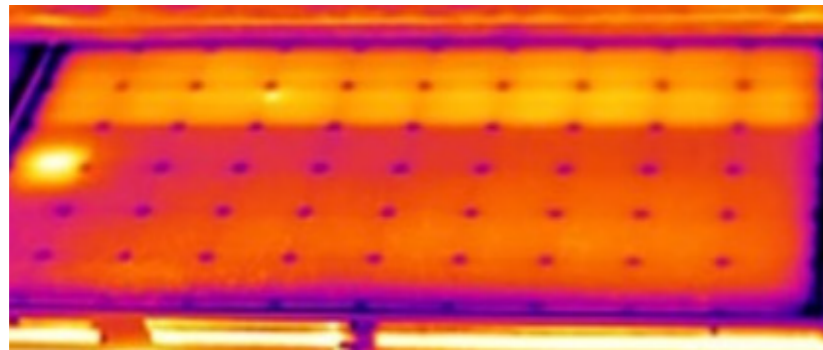
Thermographic images need experienced experts to interpret the images. The following pictures show some examples of possible findings:



In this case, IR image and a standard picture, the temperatures in the lowest cell row is caused by dirt deposit. The recommended action is cleaning

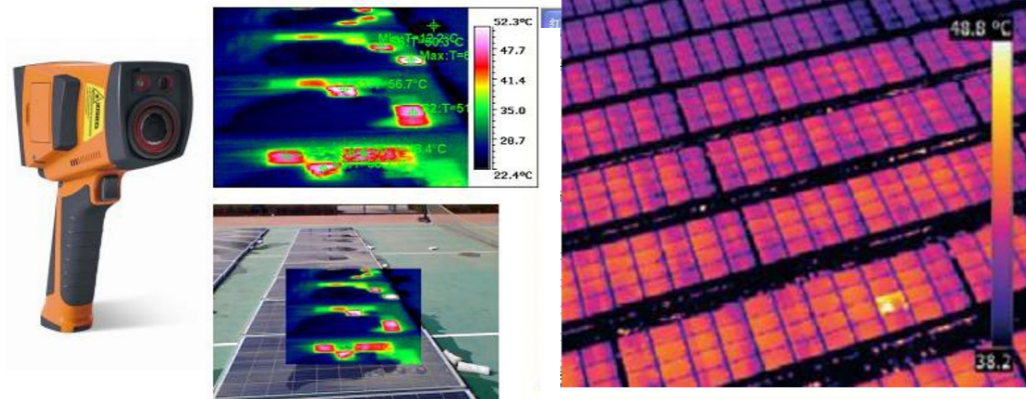


Several cells at the beginning stage of a hot spot, possible reason dirt/ debris. More detailed investigation needed

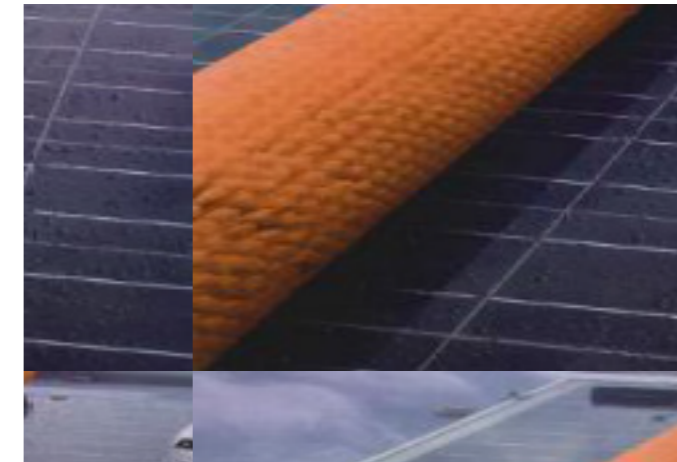


26

Cell string is too hot, hot spot, bypass diode activated, JB becoming hot



27



28



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CLEANING PROCEDURE

- It is recommended to clean the modules at least once a month, but adjust the schedule based on specific environmental conditions and module performance.
- It is recommended to do the cleaning on early morning, late afternoon, overcast days, or during the hours when the irradiation is no higher than 200 W/m². The cleaning of the modules should be carried out during cooler hours of the day to avoid thermal stress and risk of damage. Avoid cleaning when the modules are hot or under direct sunlight.
- **Water quality requirement:**
 - Water should be neutral: $6.5 < \text{pH} < 8$.
 - Water hardness: $< 450 \text{ mg/L}$.
 - Total dissolved solids: $< 1000 \text{ mg/L}$.
 - The temperature difference between water and module can't exceed 10°C.
 - Water pressure: $< 3500 \text{ kPa}$, distance between nozzle and panel $> 0.5 \text{ m}$. If using a hose or backpack-style pressure set, water pressure $< 675 \text{ kPa}$.
- Detergents, surfactants, and degreasers that are neutral or mildly acidic, citric acid or oxalic acid (oxalic acid diluted at a 1:50 ratio with water), and ethanol or methanol, can be use for cleaning.

²⁶ JinkoSolar Internal Presentation

²⁷ JinkoSolar Internal Presentation

Wet Manual Cleaning (Recommended)

1. Pre-Rinse: pre-rinse with water to loosen surface dust, dirt, and debris.
2. Sweep: gently sweep away loose debris such as dust or fallen leaves using a soft brush or cloth.
3. Scrap: or stubborn residues such as dirt, bird droppings, or any sticky substances firmly adhered to the module that won't budge with sweeping, use a plastic scraper or gauze for a more thorough scrubbing treatment.
4. Rinse: start with a simple water flush for clear surfaces. If dust is present, flush first, brush gently, and then rinse. For stubborn stains like plant juices, combine water with a soft brush for effective cleaning, followed by a thorough rinse.
5. Squeegee (optional): to achieve better cleaning results, we recommend using a squeegee to remove excess water from the surface after rinsing.

Air Cleaning

1. Jinko Solar recommends using this method to clean the soft dirt (like dust) on modules. This technique can be applied if the method is efficient enough to clean the modules considering the on-site conditions.
2. Choose cold air, do not use hot air to clean the module, 10 cm away from the clean area of the module, turn on the cleaning equipment switch, adjust the air pressure to 0.4-0.7 MPa, and clean at a speed of 0.1 m/s, and repeat until the module is clean.

²⁸ JinkoSolar Internal Presentation

²⁹ JinkoSolar Internal Presentation

Special Cleaning - Accumulated Snow

1. While Jinko modules can withstand high snow loads (refer to the installation manual), snow can affect the module’s power generation performance and may cause ice formation on the surface. Therefore, Jinko recommends timely snow removal to enhance the output power. When snow removal is necessary, please use tools that will not damage the module surface, such as a brush or mop, to gently clear all snow and prevent any localized snow accumulation on the PV modules.
 2. Furthermore, it is strictly prohibited to use hot water to melt snow or ice on the module surface, as it may cause a thermal shock and possible glass breakage. The use of forceful methods or destructive tools to remove snow or ice that is frozen on the module surface is also strictly forbidden.
- Do not use: nitro thinner, organic solvents, strong acids, strong alkaline, abrasive powders, scrubbing cleaners or polishing agents.
 - During the cleaning process, it is recommended to wear cleaning gloves to avoid leaving fingerprints and dirt on the glass. Do not touch the surface of the glass without gloves.
 - Do not use tools or materials that will scratch the surface of modules, such as blades, scouring wire, metal tools, and other abrasive materials.
 - Various soft foam materials, non-woven fabrics, brooms, soft sponges, soft brushes, and brushes with nylon thread that have a diameter of 0.06-0.1mm can be used.
 - For bifacial modules, ensure both the front and back are cleaned using the same methods. Take care not to directly wash the junction box with water and always keep connectors clean and dry to prevent electrical hazards.
 - When cleaning the back surface of the bifacial module, avoid any sharp objects that may cause damage or penetrate the base material. Other cleaning requirements are the same as those for the front side cleaning.
 - The amount of electricity generated by a PV module is proportional to the amount of light captured, and a module with shaded cells will generate less energy, moreover, dirt or foreign objects like bird droppings and leaves left on the front side of the module will cause safety risks, such as hot spot issues, therefore, it is important to keep PV modules clean.
 - For more cleaning instructions please contact cs.eu@jinkosolar.com

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