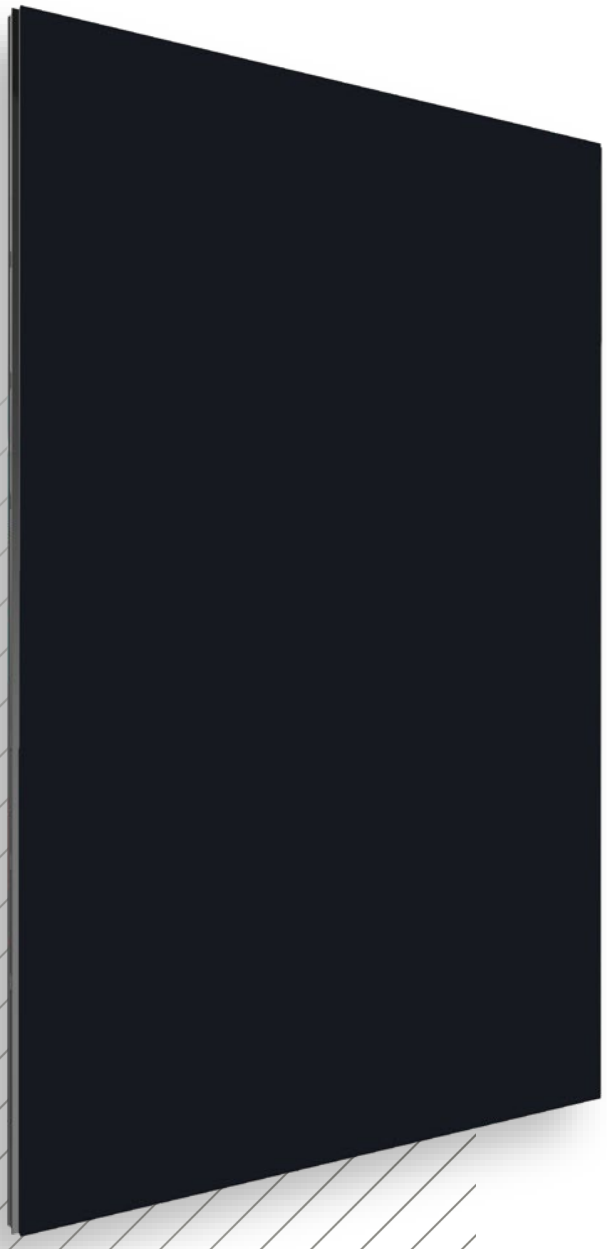
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First Solar Series 6 *Plus* Modules | USER GUIDE

MPD-00594-06



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CONTACT INFORMATION

For information regarding First Solar and its products, please visit www.firstsolar.com. First Solar has an extensive library of supporting Application Notes that can be made available upon request from technical support technicalsupport@firstsolar.com.

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1 INTRODUCTION

This document provides information on First Solar Series 6 *Plus* modules of model types beginning as FS-6XXX-P ("XXX" references the module power rating) for system designers, installers, and maintenance personnel. Model types including 'A' contain an anti-reflective coating (ARC) on the front side surface.

Series 6 *Plus* modules are designed to have a long operating life and high energy yield when installed, operated, and serviced in accordance with the instructions in this User Guide. Read this User Guide thoroughly before beginning any work related to installation, operation, or maintenance of the First Solar Series 6 *Plus* module.

Please refer to your First Solar Module Warranty Terms & Conditions for module warranty terms and product return policies. Failure to follow this User Guide may void your warranty.

Keep this User Guide for future reference and provide to all subsequent owners or users of the solar modules. Updates may be found at www.firstsolar.com.

2 SAFETY

All instructions and safety information should be read and understood before attempting to handle, install, or electrically connect First Solar modules. Failure to follow safety, installation, and handling instructions may result in injury. Only qualified personnel should install, operate, or maintain PV modules or systems.

Series 6 *Plus* modules are designed for 1000 V systems at altitudes up to 5000 m (16404 ft) per IEC 61730 and 4000 m (13123 ft) per UL 61730. Series 6 *Plus* modules are designed for 1500 VDC systems at altitudes up to 3000 m (9842 ft) per IEC 61730 and 2000 m (6561 ft) per UL 61730.

Select installation locations and module support structures to ensure modules and connectors (open or mated) are never submerged in standing water.

DANGER



Series 6 *Plus* modules may produce up to 280 Volts DC (VDC) and up to 4.0 A when exposed to sunlight. The danger increases as modules are connected together in series and/or parallel.

A single module or multiple interconnected modules can create a lethal shock hazard during daylight hours, including periods of low light levels.

DANGER



To avoid fire and/or injury due to ground faults and associated electrical hazards:

- Do not unplug PV module connections while under load. Do not disconnect the module connectors during daylight hours unless the module is in an open circuit condition.
- Replace modules with damaged wires immediately. Keep all array wiring out of reach of non-qualified personnel.
- Do not concentrate light on the module in an attempt to increase power output.
- Never allow the PV array system voltage to exceed 1500 VDC under any condition.
- Replace broken modules immediately.
- Repair ground faults immediately.
- Do not work on modules or systems when the modules or wiring is wet.
- All building mounted PV systems should utilize Ground Fault Detector Interrupters (GFDI) and ARC Fault Circuit Interrupters to minimize risk of electrical shocks and fires.

Series 6 *Plus* modules have a maximum overcurrent protection rating of 5.0 A as defined by IEC/UL 61730-1 and IEC/UL 61730-2. PV systems should be designed to comply with and provide module overcurrent protection consistent with local codes.

The conditions necessary to trigger reverse current overload (RCOL) do not occur in typical operating modes of a properly installed PV system. The system designer should ensure that modules are not subjected to RCOL. The use of GFDI devices or other advanced fault monitoring techniques can significantly reduce the likelihood of sustained ground faults. Properly selected and installed string fuses can increase protection against RCOL.

DANGER



Reverse currents higher than the rated values for a First Solar module, may result in module failure, including module breakage due to RCOL. Extreme and continuous RCOL conditions may cause a fire or create electrical shock hazards. To avoid RCOL:

- Maintain equivalent voltage in parallel strings by installing an equal number of modules per string within the same source circuit. Failure to install modules with balanced voltage in parallel strings can result in voltage imbalance.
- Incorporate measures to protect modules against RCOL for connections of parallel strings.

Modules damaged because of system-induced RCOL are not covered under the First Solar Module Warranty. Module warranty eligibility is not affected by the presence, absence, or type of reverse current protection used in a system design.

CAUTION



Wear safety glasses and **cut-resistant gloves** when working with non-interconnected modules or system components.

Wear electrically rated PPE when working with interconnected modules or system components. Select PPE based on work consistent with local and/or national standards.

WARNING



To avoid risk of fire, do NOT interconnect Series 6 *Plus* modules with other FS Series modules (e.g. – Series 4, Series 3, or Series 2) within the same interconnected string, inverter, or Maximum Power Point Tracker.

3 REGULATORY COMPLIANCE

It is the responsibility of the installer and/or system integrator to ensure compliance with all local structural and electrical codes, which may be applicable to the installation and use of First Solar Series 6 *Plus* modules.

For systems installed in North America, First Solar Series 6 *Plus* modules are Listed by a Nationally Recognized Test Laboratory (NRTL) to UL 61730, the standard for Flat-Plate Photovoltaic Modules and Panels. To maintain the modules' application as a UL Listed product:

- Use only components that have been Recognized or Listed by Underwriters Laboratories (UL) for their intended purpose.
- Ensure the PV array open-circuit voltage does not exceed 1500 VDC.
- Install modules with mounting systems that have been evaluated for UL Listed application.
- Protect modules from reverse currents in excess of the 5.0 A maximum series fuse rating.
- The module is considered to be in compliance with the applicable UL standard only when the module is mounted in the manner specified by the mounting instructions in this User Guide.
- A module with exposed conductive parts is considered to be in compliance with the applicable UL standard only when it is electrically grounded in accordance with this User Guide and the requirements of the National Electrical Code, ANSI/NFPA 70.

Series 6 *Plus* modules are tested and certified per IEC 61730-1/IEC 61730-2 and meet Class II requirements for 1500 VDC systems.

Series 6 *Plus* modules are tested and certified per IEC 61215-1/IEC 61215-1-2/IEC 61215-2 for a maximum system voltage of 1500 VDC.

4 PRODUCT IDENTIFICATION & RATINGS

4.1 PRODUCT IDENTIFICATION & RATINGS

Each module is equipped with a product label on the back and laser-etched identification on the front glass. The label identifies the model number, nameplate electrical ratings, and safety information.

The module Rated Power is denoted in the 'XXX' position of the base Model Number format of FS-6XXX-P. (Example: FS-6460A-P has a Rated Power of 460W)

The ratings in Table 1 are UL Listed with a tolerance of ±10% unless otherwise noted.

Note: Electrical specifications are subject to change. See label for final electrical ratings.

Table 1: Model Numbers & Ratings at Standard Test Conditions (STC[1])

RATED POWER[2] (-0/+5%)	VOLTAGE AT PMAX	CURRENT AT PMAX	OPEN CIRCUIT VOLTAGE	SHORT CIRCUIT CURRENT	MAX SYSTEM VOLTAGE	MAX SERIES FUSE
P_{MAX}(W)	V_{MAX}(V)	I_{MAX}(A)	V_{OC}(V)	I_{SC}(A)	V_{SYS}(V)	I_{CF}(A)
390.0	173.9	2.24	214.8	2.49	1500	5.0
395.0	175.0	2.26	215.4	2.50		
400.0	176.1	2.27	216.1	2.51		
405.0	177.2	2.29	216.8	2.52		
410.0	178.3	2.30	217.4	2.52		
415.0	179.3	2.31	218.1	2.53		
420.0	180.4	2.33	218.5	2.54		
425.0	181.5	2.34	218.9	2.54		
430.0	182.6	2.36	219.2	2.54		
435.0	183.6	2.37	219.6	2.55		
440.0	184.7	2.38	220.0	2.55		
445.0	185.7	2.40	220.4	2.56		
450.0	186.8	2.41	221.2	2.57		
455.0	187.7	2.42	222.0	2.58		
460.0	188.8	2.44	222.9	2.59		
465.0	189.8	2.45	223.8	2.60		
470.0	191.1	2.46	224.3	2.61		

[1] As received and stabilized ratings at STC (1000 W/m², AM1.5, (25 ± 2)°C Cell Temperature) ±10%
[2] Measurement uncertainty applies

Table 2: Temperature Characteristics

TEMPERATURE CHARACTERISTICS		
Module Operating Temperature Range	(°C)	-40 to +85
Temperature Coefficient of P_{MAX}	$T_k(P_{MAX})$	-0.32%/°C (Temperature Range: 25°C to 75°C)
Temperature Coefficient of V_{OC}	$T_k(V_{OC})$	-0.28%/°C
Temperature Coefficient of I_{SC}	$T_k(I_{SC})$	+0.04%/°C

4.2 SYSTEM DERATING FACTORS

Under normal operation, a PV module may experience conditions that produce higher current and/or voltage than reported at STC. Accordingly, the values of Isc and Voc listed for STC should be multiplied by a factor of 1.25 when determining component voltage ratings, conductor current ratings, and size of controls connected to the PV output. For UL installations, an additional 1.25 safety factor for short circuit current may be applicable, reference the National Electric Code (NEC) Article 690 for further details. Specific site conditions and local electric code requirements must be used for determining the maximum system voltage.

When calculating module Voc at 125 mW/cm^2, AM1.5 spectrum, and cell temperature of -10°C, multiply the specific model type STC listed Voc value by a factor of 1.109. When calculating module Isc at 125 mW/cm^2, AM1.5 spectrum, and cell temperature of 75°C, multiply the specific model type STC listed Isc value by a factor of 1.275.

5 HANDLING & STORAGE

5.1 HANDLING & STORAGE

When handling packs using forklifts or other mechanical aids, ensure uniform pack support, and the forks fully extend under the pallet. Packs can be lifted from either the short or long side of the pallet. Forklifts must engage the pallet a minimum of 1.3 m (51 in) for long side engagement and a minimum of 1.5 m (60 in) for short side engagement. Failure to meet engagement lengths may damage pallet and modules on bottom of pack.

Modules on a pack may lean or shift on a pallet during shipping. It is recommended to unload shifted packs one at a time. Do not unload or lift stacked packs from the short side. If any damage is observed, use the Delivery Note to document affected pallets and contact technicalsupport@firstsolar.com.

Only originally banded, fully intact and loaded packs may be stacked for storage up to two high for three weeks on site or extended periods in a warehouse. Packs should not be stacked if rebanded on site, if any corner braces or top cap material has been removed, or if any banding is broken from the pack.

- Do not transport stacked packs around project site.
- Do not attempt to transport the pack once the straps have been removed.

Please evaluate site conditions for safe pack storage as uneven or recently disturbed ground and moisture may affect pack stability. Packs are not intended for long-term outdoor storage. Packs should not be exposed to standing water higher than half the height of the pallet.

WARNING



Open the packaging with care. A single person should not attempt to lift a Series 6 *Plus* module. **Lift the modules from the pallet with two or more persons or with lift assist.** Do not attempt to lift multiple modules off the stack at the same time.

During handling and installation, do not make abrasive contact with top glass surface to prevent scratches of ARC film.

The pack's cap includes two green markings for module orientation purposes. The long edge orientation mark corresponds to the side of the module with the positive junction box cable.

5.2 MODEL TYPE DIFFERENTIATION

The Series 6 *Plus* module includes model numbers of FS-6XXX-P, FS-6XXXA-P, FS-6XXX-P-I, and FS-6XXXA-P-I ("XXX" references the module power rating). The model types are differentiated by the following factors:

- Model number presence on the module product label and pack label
- Color of the module product label and pack label (Figure 1)
- Quantity of holes at each end of the long frame side (Figure 2)

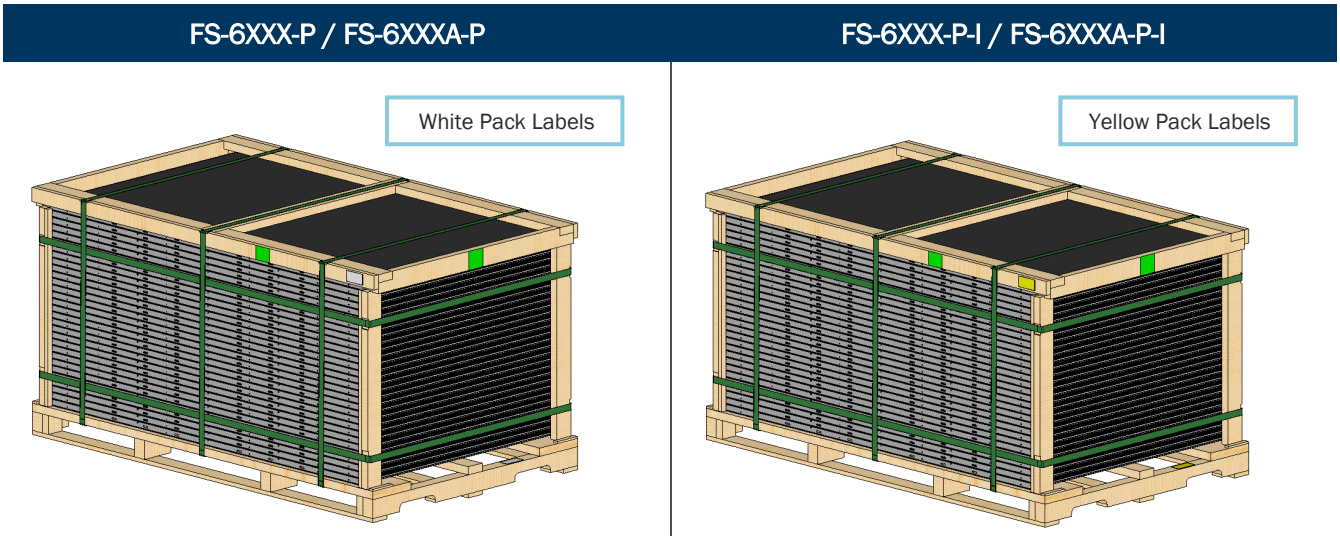


Figure 1: Pack Label Color Differentiation

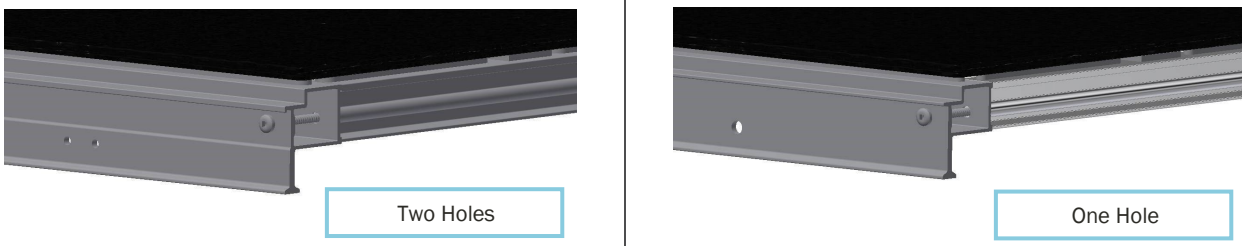


Figure 2: Differentiation Holes on Long Edge Frame Isometric View

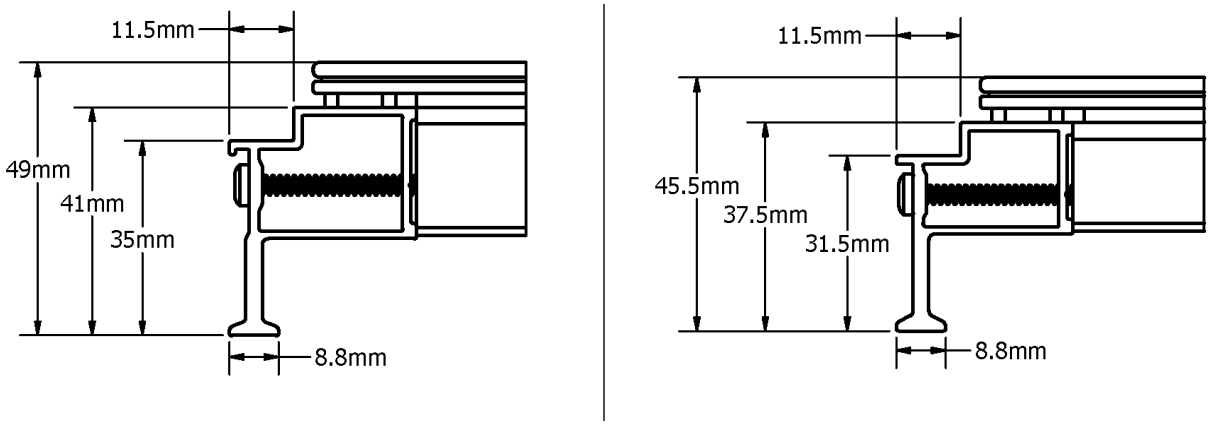


Figure 3: Long Edge Frame Detail

6 MECHANICAL SPECIFICATIONS

Table 3: Series 6 *Plus* Module Mechanical Specifications

SPECIFICATION	SERIES 6 *PLUS* MODEL TYPE	
	FS-6XXX-P / FS-6XXXA-P	FS-6XXX-P-I / FS-6XXXA-P-I
Module Weight[3]	34.9 kg +1.5/-2.5 kg (76.9 lbs +3.3/-5.5 lbs)	34.2 kg +1.5/-2.5 kg (75.4 lbs +3.3/-5.5 lbs)
Height	49 mm ± 1 mm (1.9 in ± 0.04 in)	45.5 mm ± 1 mm (1.8 in ± 0.04 in)
Length	2024 mm +3/-1 mm (79.7 in +0.11/-0.04 in)	
Width	1245 mm ± 2 mm (49.0 in ± 0.08 in)	
Total Area	2.52 m² (27.1 ft²)	
Junction Box Lead Wire[4]	2.5 mm² (14 AWG) 733 mm (28.86 in) (+) & Bulkhead (-)	
Fire Performance[5]	Type 19: Class A Spread of Flame / Class C Burning Brand	

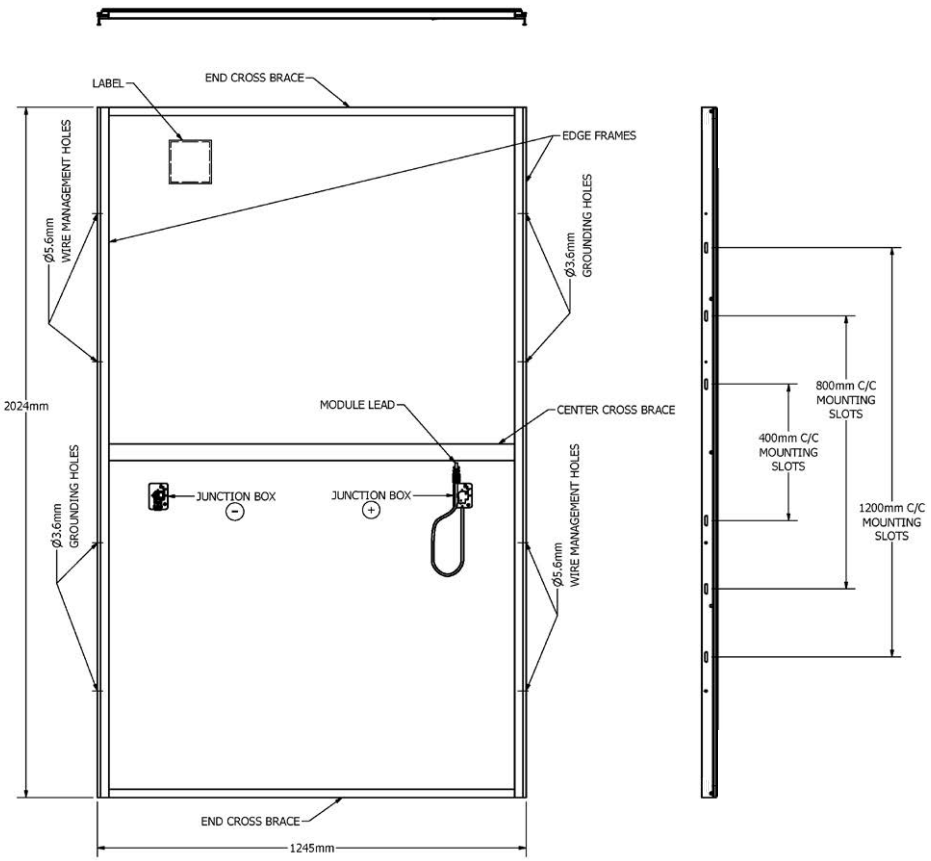


Figure 4: Series 6 *Plus* Module Mechanical Drawing

[3] When designing structure components for systems with mixed model types (mixed '-P' and '-P-I' model suffixes) the larger nominal weight should be used to enable flexibility to utilize '-P' modules universally in any array mounting position.
[4] Length from junction box exit to connector mating surface
[5] Module UL 61730 fire rating is valid only when mounted in the manner specified in this User Guide. Roof mounted fire rating is established by assessing rack and module as a unit. External fire source resistance has not been evaluated.

7 INSTALLATION & MOUNTING

7.1 MOUNTING

It is best practice to complete heavy construction and trenching prior to module installation to minimize module exposure to dust. Ensure any site preparation or maintenance chemicals (soil binding agents or chemicals used for on-site dust control or weed control) do not spray, splash, or drift onto the surface of the modules or its associated components.

It is the responsibility of the qualified engineer and/or qualified installer to ensure the system and its components meet applicable structural and electrical code requirements for the product application's jurisdiction. First Solar is not responsible for bonding failure, breakage, damage, wear, corrosion, or module performance issues that are deemed to be caused by design or installation practices that do not comply with this User Guide.

CAUTION



Safety hazards or potentially unsafe practices:

- Do not install the modules during high wind or wet conditions.
- Handle modules with care during installation, as heavy impact to the front, back, or edges could result in damage to the module. Do not impact module with hammer to aid installation process.
- Do not walk, stand, or sit on modules.
- Do not carry multiple modules on top of one another after removal from pack.
- Do not lift or pull on modules using lead wire or junction boxes.
- Do not rest objects (such as tools, etc.) on module glass.

Modules must have adequate ventilation and airflow to prevent operating temperatures above 85 °C.

For rooftop mounting, mount modules over a fire resistant roof covering rated for the application. The recommended minimum standoff height is 8 cm (3.15 in). Series 6 *Plus* modules may be installed at an installation angle up to 60°.

For applications where module is mounted above water (i.e. Floating PV):

- Modules may be deployed over inland freshwater, with a minimum clearance of 6 inches (15cm) above maximum design wave height for any part of module, including module lead wire and connector.
- Mounting over saltwater or brackish water is prohibited.
- Mounting structure must ensure module remains in a fixed position and isolated from wave-induced torsion and stress

7.2 MOUNTING LOCATIONS & LOAD RATINGS

The interface of the mounting structure to the module frame must meet the technical requirements specified in this User Guide. The mounting system design must provide adequate support for the module to prevent load damage from occurring based on the loading requirements for the given application and the chosen mounting locations. Structures must not come into direct contact with the surface or edges of the module glass or center cross brace(s).

Modules can be secured to the support structure with top (front side) mounting clamps or by frame slots, known as SpeedSlots™.

Series 6 *Plus* modules have been evaluated to operate in an ambient air temperature range of at least -40°C to +40°C and have been tested to wind/snow loads as detailed in Table 4. Test loads include a safety factor of 1.5 above the design loads.

Series 6 *Plus* modules meet the following load ratings when mounted as specified in this User Guide and evaluated according to the listed standard in Table 4.

Table 4: Series 6 *Plus* Module Load Ratings

Model Types	Mount Config.	Symmetrical Four-point Mount Location	IEC 61215 / IEC 61730		UL 61730	
			Design Load	Test Load	Design Load	Test Load
FS-6XXX-P FS-6XXXA-P	A	**Top Mount:** Range of 400mm to 1200 mm (C/C) **SpeedSlot Mount:** 400 mm 800 mm 1200 mm	± 1600 Pa (± 33.4 lb/ft²)	± 2400 Pa (± 50.1 lb/ft²)	± 1600 Pa (± 33.4 lb/ft²)	± 2400 Pa (± 50.1 lb/ft²)
FS-6XXX-P-I FS-6XXXA-P-I	B[6]	**Top Mount:** 1200 mm (C/C) **SpeedSlot Mount:** 1200 mm	± 1600 Pa (± 33.4 lb/ft²)	± 2400 Pa (± 50.1 lb/ft²)	± 1600 Pa (± 33.4 lb/ft²)	± 2400 Pa (± 50.1 lb/ft²)
	C	**Top Mount:** Range of 400mm to 1000 mm (C/C) **SpeedSlot Mount:** 400 mm 800 mm			+1300 / -900 Pa (+27.2 / -18.8 lb/ft²)	+1950 / -1350 Pa (+40.7 / -28.2 lb/ft²)

[6] FS-6XXX-P-I / FS-6XXXA-P-I Model Types are IEC 61215/IEC 61730 certified at Mounting Configuration B only when supplemented with additional interface point(s). Consult First Solar for supplemental documentation.

Symmetrically secure the module using a minimum of four frame contact points regardless if mounted with top clamps or with SpeedSlot clamps. Other mounting solutions not discussed in this User Guide (Such as - asymmetric mounting, higher load ratings, alternative clamp geometry, etc.) may be permitted, but require evaluation by First Solar (technicalsupport@firstsolar.com). First Solar reserves the right to reasonable access to validate proper installation.

- The modules shall have a minimum spacing gap of 6 mm (0.24 in) between each other. Usable junction box lead wire lengths accommodate spacing up to 245 mm (9.65 in) (assuming no substructure interference).
- Do not use module short edge frame sides or center cross braces for mounting unless specifically evaluated and approved by First Solar in writing.
- Do not modify the module frame in any way. This includes drilling additional holes, altering mounting features (slots), or otherwise cutting, trimming, or shaping any part of the module frame.
- Module mounting structure support under clamps must maintain a minimum bearing area length of 35 mm (1.38 in) and maintain full frame bottom flange engagement under load.
- Module attachment hardware (i.e. clamps, bolts, etc.) must not contact the module glass.
- Install clamps to the torque stated by the mounting hardware manufacturer.
- Mounting clamps certified/designed to electrically bond and/or ground the module frame are allowed when used in accordance with the clamp manufacturer's instructions.
- The maximum clamp force shall not exceed 5500 N for either top or SpeedSlot clamps.
- Minor clamp deformation under load may be acceptable as long as clamping force is maintained and the deformation does not contribute to a weakening of the clamp or dislodgement of the module.

Series 6 *Plus* modules of model types of FS-6XXX-P-I / FS-6XXXA-P-I (sometimes referred to as Series 6 *Plus* interior modules) have a reduced mechanical design load as allowed under its UL 61730 listing, depicted in Table 4. These modules are identified by "Reduced mechanical design load" wording on the module nameplate label.

Many project designs will choose to incorporate Series 6 *Plus* model types FS-6XXX-P-I / FS-6XXXA-P-I either in full, or in zoned portions of an array combined with Series 6 *Plus* model types FS-6XXX-P / FS-6XXXA-P in other zones. For these mixed design cases, use the following guidance:

- The SpeedSlot mounting interface with universally consistent interface dimensions for all Series 6 *Plus* modules is preferred in order to avoid managing the different top clamp height dimensions between the different Series 6 *Plus* model types.
- The Structural Engineer of Record must utilize the weight specification of the FS-6XXX-P / FS-6XXXA-P model types from Table 3 for structural racking design, top-of-pile calculations, and post design calculations for all array positions.

It is recommended all array positions be designed to mechanically accommodate the FS-6XXX-P / FS-6XXXA-P model types, given their ability to be utilized in all array zones. For the same reason, First Solar will typically provide these FS-6XXX-P / FS-6XXXA-P model types as spares and/or warranty replacements.

CAUTION



Model types FS-6XXX-P-I / FS-6XXXA-P-I may only be deployed in engineered PV systems, where the following conditions are met:

- UL 61730 is the applicable certification standard (in any instance where a module mounting method results in a <1600 Pa load capability per Table 4 or otherwise documented by First Solar).
- When PV modules are intended to be installed in an engineered scenario by qualified personnel such as in a ground-mounted PV power generation plant, they may be designed to meet a lower minimum test load of 1200 Pa with a safety factor of 1,5: i.e. an 800 Pa minimum design load for the down pressures (positive) and uplift pressures (negative). These modules are marked by “Reduced mechanical design load” on the nameplate followed by the range of positive and negative design loads they are designed for. As an example, these modules may be used in interior or exterior rows where the module mounting and structure in combination are designed to meet a specific design load lower than 1600 Pa and a licensed professional engineer has taken into consideration all factors below for the combined site specific wind and snow loads.
  - Pressure coefficients should be derived based on an effective wind area equal to one PV module, from boundary layer wind tunnel tests on the specific mounting system used to support the PV module.
  - Boundary layer wind tunnel tests should be conducted in accordance with ASCE 7 and ASCE 49, or other recognized industry guidance;
  - Mounting system vibrations with natural frequencies less than 10 Hz may result in loads higher than predicted from static load calculations, depending on wind speed and damping ratio of the vibration mode, and should be considered to assess dynamic amplification factors;
  - Some mounting systems may be susceptible to instabilities due to vortex shedding which may not be addressed in building codes; guidance from qualified experts in boundary layer wind tunnel testing of ground-mounted PV systems may be required to address this risk;
  - Modules when mounted on trackers that rely on being operational or stowing at a specified angle in extreme wind or snow conditions should be verified to limit loads below the design load threshold considering the design controls implemented in such trackers.
- Alternatively, modules having a higher minimum design load compatible to the required site-specific loads may be used. Reduced mechanical load modules cannot be used on a rooftop system.

7.3 TOP MOUNTING

Center each clamp +/- 12 mm (0.48 in) within mounting range or location (detailed in Table 4) to meet documented load ratings based on model type. Top mounting clamps must have a uniform frame engagement area of 9 mm (0.35 in) minimum width on the top ledge and 30 mm (1.18 in) minimum length as depicted in Figure 5. Module clamps may not continuously span the top of the frame across the midpoint of the long edge frame (to allow for module deflection). Clamps that do not meet the minimum requirements may not preserve module certifications or warranty and must be evaluated by First Solar (technicalsupport@firstsolar.com).

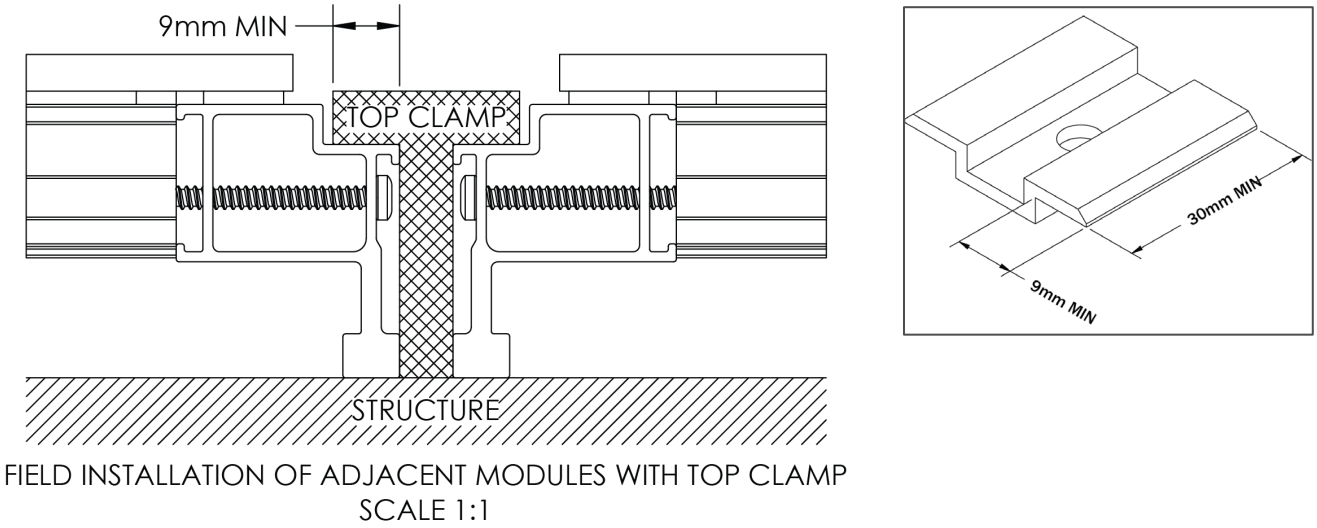


Figure 5: Shared Top Clamp Detail

7.4 SPEEDSLOT MOUNTING

The Series 6 *Plus* module frames include six SpeedSlots on each side. SpeedSlot clamps must either extend 10 mm (0.39 in) beyond the inner edge of the frame, or have a retention feature to prevent module frame dislodgement under load. SpeedSlot clamps must be at least 12 mm (0.47 in) wide from attachment point through the 10 mm (0.39 in) extension or until point of retention feature, shown in Figure 8. Clamps should rest on the flat surface of the SpeedSlot.

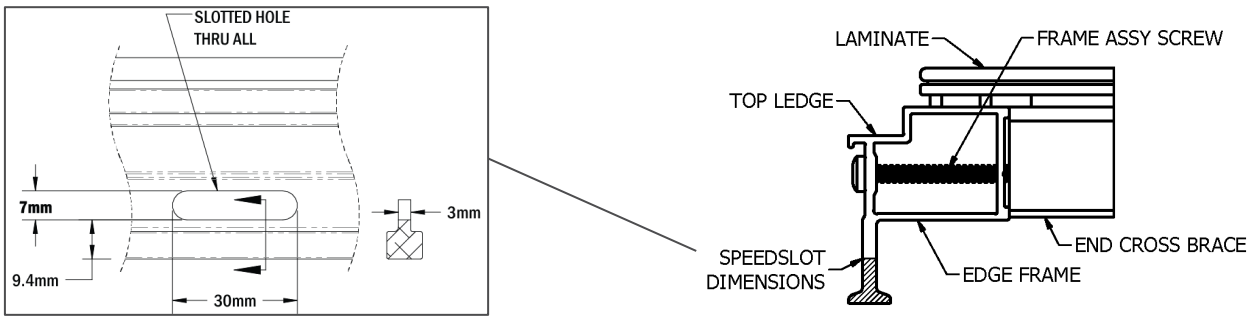


Figure 6: SpeedSlot Dimensions

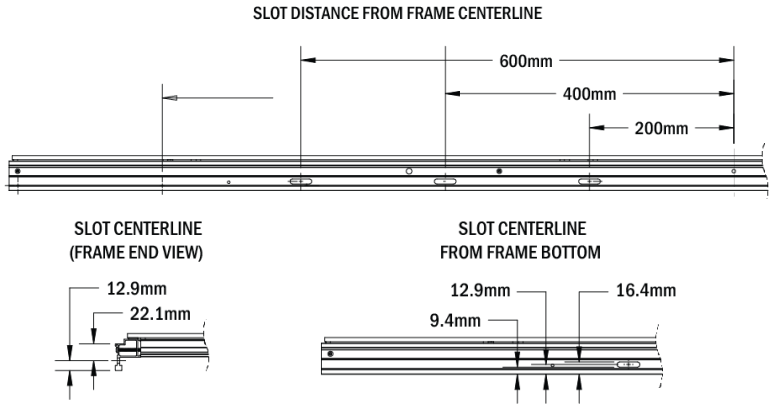


Figure 7: SpeedSlot Detail on Long Edge Frame

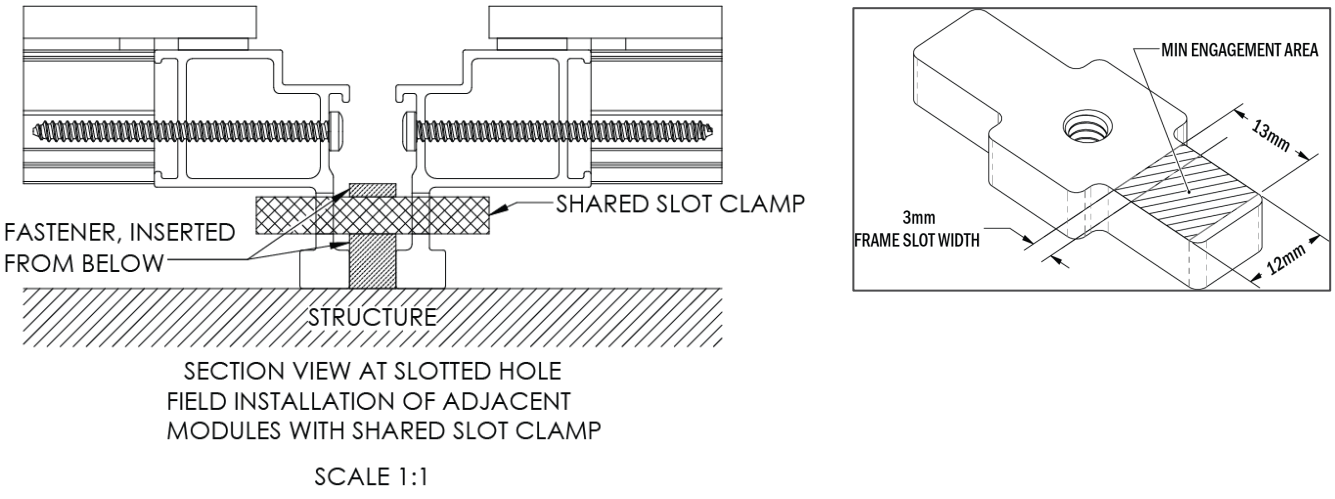


Figure 8: Shared SpeedSlot Clamp Detail

7.5 MODULE ORIENTATION

PV performance modeling software, such as PlantPredict (http://www.plantpredict.com), should be used to determine the optimum orientation and tilt angle for each location.

Mount modules in portrait orientation for applications where row-to-row shading could occur. Landscape orientation is permitted only in flat mount applications where the module long edge is not completely shaded and when compliant with Section 7.6 Module Shading Considerations.

7.6 MODULE SHADING CONSIDERATIONS

Specific shading patterns can cause damage to module cells due to the creation of localized areas of reverse bias. Reverse bias is generated by one or more series-connected cells being shaded while the rest of the cells are fully illuminated. When at-risk shading patterns occur, damage can occur in short durations (seconds to minutes) and a wide range of irradiance (as low as 160 W/m²).

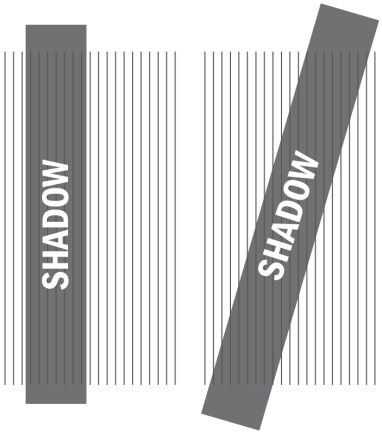


Figure 9: Example of at-risk shading patterns

There is no risk of module damage due to shading that occurs while modules are in open circuit. Shading that occurs at a distance greater than 2 m (6.6 ft), also known as diffuse shading, carries reduced risk and should be avoided where possible. Row-to-row shading of modules installed in portrait orientation is acceptable.

There is a low risk of module damage due to shading from repeatedly walking or standing in front of operating modules or from repeatedly parking or driving vehicles in front of operating modules during illuminated times. It is best practice to stay close to the backside of the adjacent rack as one travels down a row of operating modules.

Do not subject modules to high risk shading instances listed below:

- Resting or adhering slender objects (tools, brooms, clothing, wires, tape) on front-side of operating modules, or when within ~2 m (~6.6 ft) above operating modules, especially when the shadow is oriented parallel to cells
- Fixed objects within ~2 m (~6.6 ft) above operating modules that cast a shadow over the long dimension of the cells. Close objects (posts, ropes, fences, etc.) can begin to increase risk of partial shading of full cells when within ~2 m (~6.6 ft) from the front-side of operating module
- A support frame or mounting method on the long edge(s) of modules that fully shades the entire length of a cell (either partially or completely)
- Cleaning robots or other mechanisms that traverse the module while the system is operating
- Row-to-row shading when the modules are installed in landscape orientation
- Closely “stair-stepped” trackers on northerly slopes (northern hemisphere), or southerly slopes (southern hemisphere).

7.7 WIRE MANAGEMENT

All wire management shall comply with the applicable NEC/IEC codes and standards for maintaining and managing wires, as well as any applicable local requirements determined by local authorities having jurisdiction. This document includes evaluation of general wire management requirements based on interpretation of the following codes and standards and does not substitute for a comprehensive evaluation of applicable requirements:

- NEC 2017
  - 300.3(C)(2) – Conductors of Different Systems
  - 334.30 – Support and Securement Spacing
  - 338.24 – Cable Bend Radius Requirements for Type USE cable
- IEC
  - 62548:2016, 7.3.7.3 – Erection Method
  - 62548:2016, 7.3.8 – Segregation of AC and DC Circuits
  - 60364-5-52:2009, 522.8.3 – Cable Bend Radius

Below is a list of best practices that applies to the majority of wire management scenarios:

- The connectors, X/T joints, and in-line fuses should not be in direct contact with the metal frame or structure. It is recommended that insulated cables do not come in direct contact with the metal frame or structure, unless unavoidable, to minimize stresses on components.
- The installation of harnesses, harness jumpers, harness whips, and PV array cables (or “Homerun” cables) should not subject the connectors, X/T joints, and in-line fuses to tensile loads.
- Cable ties should be a minimum distance of 25 mm (1 in) from connectors, X/T joints, and in-line fuses.
- Cables should not maintain constant contact with the edges of glass-to-glass solar module laminates.
- Cable ties should be tensioned such that there is at least 13 mm (0.5 in) (two-finger-gap) between the top of the cable bundle and the bottom of the frame.

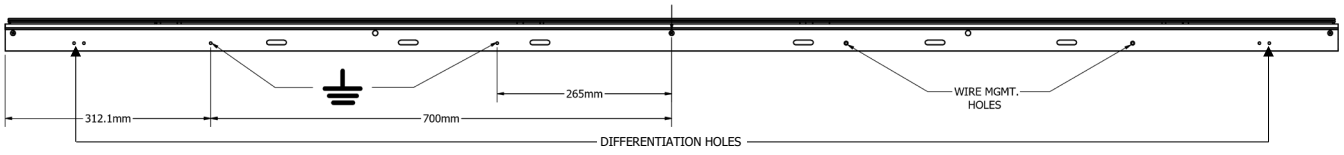


Figure 10: Grounding Hole & Wire Management Hole Detail from Frame Center[7]

[7] Quantity of differentiation holes vary based on Series 6 *Plus* model type, referenced in Figure 2.

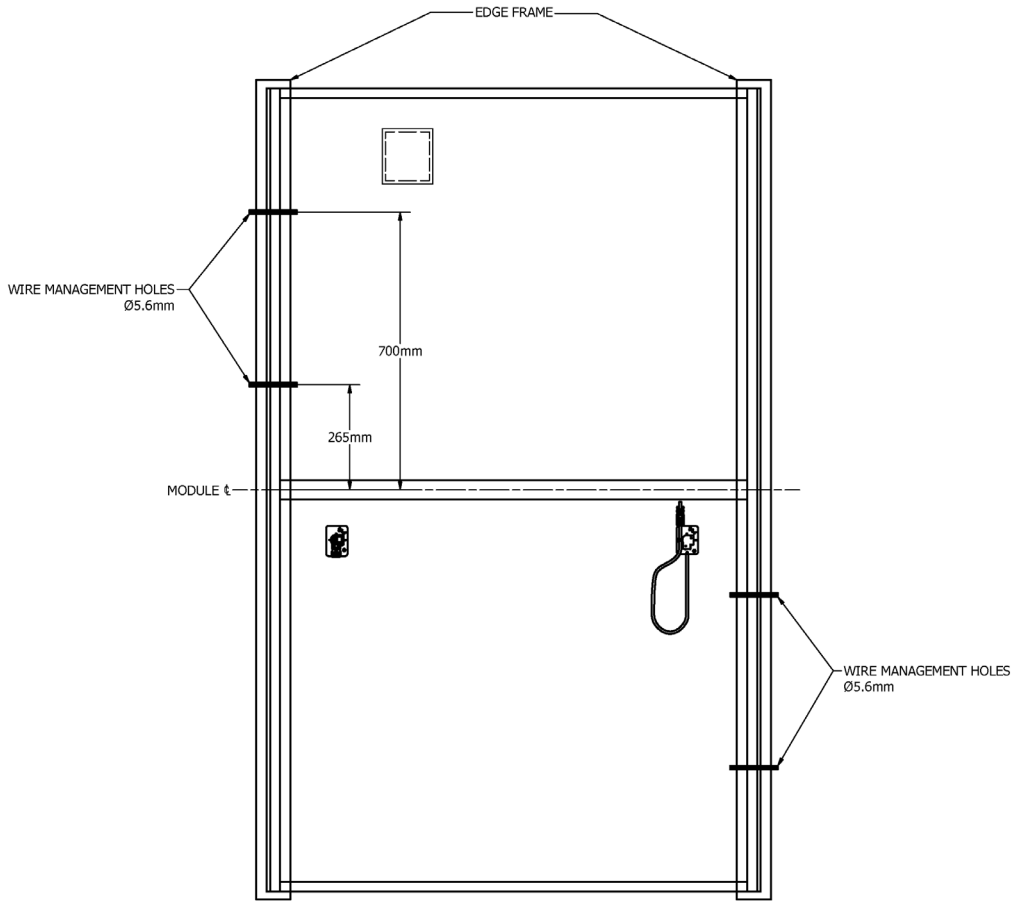


Figure 11: The above-ground DC cabling (typically a bundle of harnesses and PV array cables) may be supported by the wire management holes located on the Series 6 *Plus* module edge frames.

- Holes located 265 mm (10.4 in) from the center of the edge frame:
  - Support DC wiring bundle on Single-Torque Tube Tracker Systems
  - Support Harness end/connector (as it is being routed to the junction box)
- Holes located 700 mm (27.6in) from the center of the edge frame:
  - Support DC wiring bundle on Two-Girder Tracker and Fixed-Tilt Systems
  - Support DC wiring bundle on Single-Torque Tube Tracker Systems with moving components that extend beyond 350 mm (13.8 in) from the center of the structure.

Typically, the lead wire connection does not require wire retention or securement due to the proximity of the junction boxes on adjacent modules.

Above-ground DC cabling (typically a bundle of harness and homerun PV cables) may be supported by utilizing the wire management holes located on the frame. The module frame includes four 5.6 mm (0.22 in) wire management holes in locations depicted in Figure 11. The maximum cable weight carried by each module in totality may not exceed 3.5 kg (7.6 lbs). Do not use junction box for wire management attachment.

7.8 ELECTRICAL INTERCONNECTION

All electrical components that are interconnected to modules must have an operating voltage range that matches the maximum power point of the array, and be capable of operating the array at the maximum power point at all times. Short circuit operation is permitted only during short duration system safety testing or in fail-safe system states.

Series 6 *Plus* modules are pre-configured with industry standard connectors that are "touch proof" with all live parts protected against accidental contact and protected against polarity reversal. The cables and connectors are UV and weather resistant from –40 °C to +85 °C, and rated for 1500 VDC.

Series 6 *Plus* modules use TE Connectivity produced (https://www.te.com) PV4-S connectors (PV4-S1F/PV4-S1M). Module-to-module and module-to-harness interconnection must utilize the same manufacturer and type of connectors. First Solar cannot guarantee that connectors from different manufacturers or type of connectors will be mateable. Any damage to the module resulting from any such interconnection will not be covered by the First Solar module warranty.

CAUTION



Damaged wires, connectors, or junction boxes may cause ground faults, and associated electrical hazards, including electrical shock. To avoid these conditions:

- Protect unmated connectors from dust and moisture by using sealing caps (not provided, available from connector manufacturer).
- Limit module connectors to 10 or fewer plug cycles.
- Do not pull junction box lead wires tight. After installation, connected wire must not be under stress or tension.
- The minimum module junction box lead wire bend radius is five times the wire diameter. Observe minimum bend radius specifications on all other PV system wiring.
- Do not use junction box assembly to bear weight greater than that of a (properly wire managed) module's own wire and mated connection.
- Secure wire or connected components so they are hanging greater than 0.46 m (1.5 ft) above the ground in free field applications, and so they are hanging clear of roof coverings or pooled water in rooftop applications.
- Ensure connectors are fully mated and locking clip on connector engages.
- Do not loosen, alter, or modify the factory-installed connectors on the module junction box. Do not attempt to unscrew or tighten connector back nut.
- Ensure wire securement methods, such as use of cable ties, do not damage wire insulation.
- Ensure wires are not in contact with sharp edges of the mounting structure to avoid abrading the wire sheath.
- Inspect and maintain wire management requirements over the life of the plant.
- Do not expose modules, wires, junction box, or connectors to environments with the following substances, as they may incur damage and affect module safety or performance: greases, oils, lubricants, plasticizers and organic solvents (including aliphatic hydrocarbons, aromatic, hydrocarbons, halide hydrocarbons, ketones, alcohols, ethyl acetate, tributhyl phosphate, kerosene and gasoline).

Wiring harnesses are recommended in system designs. The shorter string size and low string current of Series 6 *Plus* modules make it possible to connect multiple strings together in parallel and return a single pair of DC cables to the combiner box or string inverter. Design wiring harnesses that are optimal for the structural layout. For example, a structure with 84 modules per row typically uses two, 7-string harnesses in the DC design in a 1500 VDC system.

Components used to interconnect the modules must be compatible with the connectors, and provide proper system operation and fault protection as required by applicable codes. Field wiring must be rated for 90°C and be of a type approved for use in accordance with the NEC (US only).

Positive Connector

Negative Connector
(integrated as part of module bulkhead junction box)



Figure 12: PV4-S Connectors of Part Numbers (PV4-S1F/PV4-S1M)

7.9 INVERTER COMPATIBILITY

Series 6 *Plus* modules are compatible with a range of string, central, transformer, and transformerless inverters. When connecting modules or module strings in series ensure inverter ratings are appropriate.

Do not exceed system design voltage and inverter design specifications when connecting modules in a series string. This is typically ensured by limiting series strings to four modules for 1000 VDC applications or six modules for 1500 VDC applications. Do not connect modules in parallel. Strings of modules can be installed in parallel for DC collection purposes.

The Maximum Power Point (MPP) voltage of a module array must be considered for compatibility with the specified inverter MPP window. Similar to the maximum open-circuit voltage, the MPP voltage of the array is dependent on ambient conditions, and the system should be designed to ensure the array MPP voltage remains within the MPP window for expected operating conditions.

7.10 GROUNDING METHOD

First Solar recommends Series 6 *Plus* modules be used in negative-grounded systems. Modules must not be subjected to negative voltage bias conditions that can occur in voltage floating or bi-polar systems (subjecting modules to conditions that could drive potential induced degradation). If string inverters or other non-negative grounded system architectures are used, alternate methods of preventing negative voltage bias on modules (such as system level voltage controllers/float controllers or integrated inverter array voltage control) must be implemented and include a minimum of hourly logged PV (-ve) to ground voltage to demonstrate compliance in event of a future warranty evaluation. Series 6 *Plus* modules must not be used in positive-grounded systems.

Utilize marked grounding holes (see Figure 13) in frame. Where using common grounding hardware (lugs, nuts, bolts, star washers, split-ring lock washers, flat washers and the like) to attach grounding/bonding device, the attachment must be in conformance with the grounding device manufacturer's instructions. Grounding/ bonding devices must meet the IEC/UL 61730-2 the pass/fail criteria of a 100 mΩ resistance.



Figure 13: Grounding Mark

NORTH AMERICAN PROJECTS ONLY

For North America, a module with exposed conductive parts is considered to comply with UL 61730 only when it is electrically grounded in accordance with the instructions presented and the requirements of NFPA 70: National Electrical Code, article 250.

The module is considered to be in compliance with this standard only when the module is either mounted in the manner specified by the mounting instructions, or when the mounting means has been evaluated with this PV module to UL 2703. A module with exposed conductive parts is considered to be in compliance with this standard only when it is either electrically grounded in accordance with the manufacturer's instructions and the requirements of the National Electrical Code, ANSI/NFPA 70, or when the bonding means has been evaluated with this PV module to UL 2703.

Grounding kits containing #8-32 (M4x0.7) self-threading stainless steel components (Example: self-threading screw, flat washer, cup washer, and toothed washer) or other compatible UL listed hardware can be used to attach copper grounding wire to one of the frame's marked grounding holes per manufacturer instructions. Example: Slide the flat washer on the screw, followed by the cupped toothed washer with the smaller end of the cup washer closest to the cap bolt head. Affix the copper grounding wire between the flat washer and the cupped toothed washer and tighten the screw securely into the frame grounding hole.

Common hardware items (such as nuts, bolts, star washers, lock washers and the like) that have not been evaluated or certified for electrical conductivity or for use as grounding devices, should be used only for maintaining mechanical connections and holding electrical grounding devices in proper position for electrical conductivity. Such devices, where supplied with the module and evaluated through the requirements in UL 61730, may be used for grounding connections in accordance with the instructions provided with the module.

In order to provide a reliable grounding connection to the module frame, the following hardware or equivalent is required per UL 61730:

- A UL Listed Grounding Lug with paint cutting star washer and #8-32 by 3/8 inch thread forming screw.
- A UL Listed grounding strap type EM2050 as manufactured by Electric Motion CO. Inc.
- Grounding means must be secured to grounding hole opening on frame and torqued to 25 in-lbs.

Mounting clamps that are UL listed for grounding/bonding may be used in instances where the structure and module have been tested to meet UL 2703.

8 MAINTENANCE

8.1 MAINTENANCE

Only qualified personnel should perform maintenance on PV systems. Maintenance (cleaning, electrical inspection, etc.) may pose a risk of electrical shock, injury, or module damage.

A regular inspection and maintenance schedule should include, but is not limited to:

- Annually at a minimum, inspect modules for any signs of damage or broken glass. Replace broken modules immediately.
- Keep modules free from debris, particulates, or large volumes of snow to maximize system performance.
- Ensure the module surface pressure is at or below the design load by removing snow.
- Inspect wiring and wire management periodically.
- Inspect and confirm electrical connections are tight and corrosion free.
- Avoid using brush/ground maintenance tools (Example: weed trimmer, brush cutter, etc.) that could send projectiles toward module glass.

The most common causes of lower than expected PV system power output are:

- Improperly calibrated or malfunctioning monitoring equipment
- Inverter failure
- Improper or faulty field wiring or connections
- Blown fuses or tripped circuit breakers
- Excessive amounts of dirt and dust on the modules
- Shading of modules by trees, poles, or buildings

It is normal for the modules to exhibit visual irregularities, which do not impact power. ARC modules are more likely to exaggerate the visual appearance of scratches, fingerprints, and other blemishes due to the optical properties of the glass interface.

Snowdrifts may result in a non-uniform loading of modules. If it is expected that snow loads will exceed design, clear snow from modules to ensure that ice/thaw/freeze cycles under snow drifts do not result in excessive stresses on the module.

Varying snow conditions may be cleared from the modules when using dry cloths or mops. Other snow clearing methods, such as blowers, may be used depending on snow conditions and if approved by First Solar. To prevent pile up and overload, periodically clearing snow from the bottom modules first in an array is a critical process.

8.2 MODULE CLEANING GUIDANCE

Modules do not require cleaning in most climates. Installed modules may collect a light layer of dust and/or dirt (soiling) over time and periodic rainfall should be sufficient to remove light soiling in most cases. In locations with heavy soiling, properly timed module cleaning can improve energy yields.

CAUTION



Cleaning activities create risk of damage to the modules and array components, as well as the potential for electric shock.

Cleaning may reduce energy enhancing effects of anti-reflective coating.

CAUTION



Cracked or broken modules represent a shock hazard due to leakage currents and the risk of shock increases when modules are wet. Before cleaning, thoroughly inspect modules for cracks, damage, and loose connections.

The voltage and current present in an array during daylight hours are sufficient to cause a lethal electrical shock.

Only properly trained personnel who understand the risks of applying water to electrical components should clean modules. Trained personnel shall wear appropriate electrically insulating Personal Protective Equipment (PPE) during cleaning, inspection operations, or when working near modules. Professional cleaning services trained to work on live electrical systems are available for hire.

Clean modules only when in open circuit (reference Section 7.6 Module Shading Considerations) – either disconnected from load, or during times when the inverter is off. The recommended time to clean modules is from dusk to dawn when production is not affected and risk of electrical shock hazard is minimized. The following guidelines minimize impact to plant power generation, reduce safety hazards, and minimize risk of module damage.

Important

First Solar does not warrant against breakage, damage, wear, or module performance issues that are determined to be caused by module cleaning.

Cleaning Recommendations

- When dry cleaning, [it is recommended to] use soft mops or soft cloths only.
- When using water, RO water provides the best results. When RO water is not available, tap water with low mineral content (total hardness <75 mg/L) or deionized water may be used. Calcium should not exceed 75 mg/L.
- Fresh water (TDS < 1500 mg/L) may be used to clean the modules. If needed, a mild, non-abrasive, non-caustic detergent with a final fresh water and detergent solution mix between 6.5 < pH < 8.5 at 25 °C may be used. Do not use abrasive cleaners or degreasers, cleaning solutions containing hydrochloric acid, D-Limonene, ammonia, or sodium hydroxide.
- Water temperature must be < 20 °C from module temperature applied with water pressure < 35 bar (500 psi) at nozzle.
- Water must be free of floating oil or other immiscible liquids, floating debris, excessive turbidity, and objectionable odors.
- Chlorides should not exceed 250 mg/L and water conductivity should be < 250 mS/cm.
- If necessary for localized cleaning, excessively soiled spots on modules (i.e. bird droppings) may be spot-cleaned with soft cloth or mop and water.
- Do not direct pressurized water at sealed interfaces of module (junction box, edge seal, and connectors).
- Avoid cleaning backside of modules to prevent accidental stress to lead wire or junction box.

Cleaning solutions vary in design and size and can affect the load dispersed onto the modules.

First Solar recommends no more than 40.8 kg (90 lb) per module that is evenly distributed while cleaning.

- Specific contact points (wheels or belts) can affect the load and pressure placed on the modules.
- First Solar recommends the load scenarios below not be exceeded:
    - Point loads (P1)
        - Max of 13.6 kg (30 lb) each spaced 40.6 cm (16 inches) apart
    - Up to 0.18 kg/cm (P2) (1 lb/inch) of contact length for a drive belt anywhere on the module
    - Up to 0.18 kg/cm (P3) (1 lb/inch) of contact length for brushes contacting the module anywhere on the module
    - Some combination of the above load types so that P1 + P2 + P3 $\leq$ 40.8 kgf (90 lbf)
- Cleaning solutions must not affect or jeopardize any part of the mounting system.
    - This includes all parts of the mounting system: clips, rails, and trackers
- Minimize vibration from the cleaning apparatus to prevent shifting of the modules in their mounting hardware.

8.3 MODULE DISPOSAL

Modules may be recycled or disposed of in accordance with applicable local requirements.

Please visit www.firstsolar.com/modules/recycling for further details on the recycling program.

9 REVISION HISTORY

REVISION NUMBER	AMENDMENT DETAILS	REVISION DATE
1.0	Document created	3/25/2021
1.1	Module cleaning guidelines updated	7/1/2021
1.2	Addition of higher bins and updated packaging images	10/27/2021