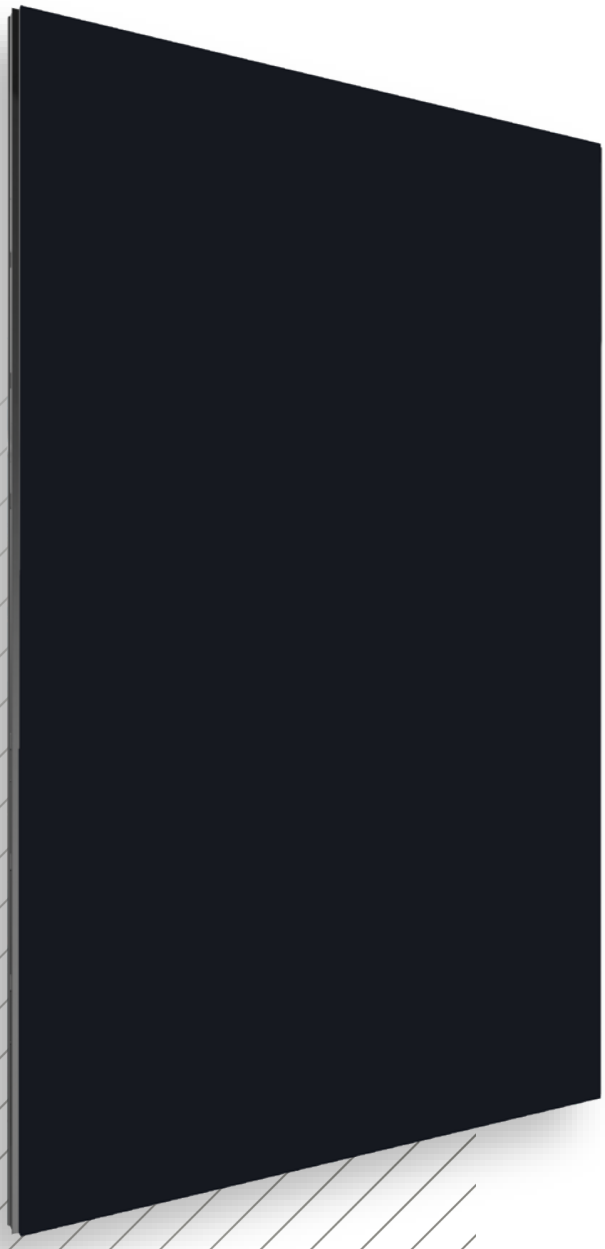
Global
REV 2.3

First Solar Series 6 *Plus* and Series 6 *Plus* Bifacial Modules | USER GUIDE

MPD-00594-06-G

Not intended for residential use in USA or rooftop applications, including commercial and industrial



First Solar

NOTICE

First Solar reserves the right to make changes in solar module design and/or specifications at any time without notice. Accordingly, the reader is cautioned to verify that data sheets are current before placing orders or finalizing system permitting and/or design. Information furnished by First Solar is believed to be accurate and reliable. However, no responsibility is assumed by First Solar or its subsidiaries for its use; nor for any infringements of patents or other rights of third parties, which may result from its use. No license is granted by implication or otherwise under any patent or patent rights of First Solar or its subsidiaries.

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.

GLOBAL

First Solar, Inc.
P.O. Box 730
Toledo, OH USA 43697-0730
Tel: +1 (602) 414-9300
Fax: +1 (602) 414-9400

TABLE OF CONTENTS

1 INTRODUCTION

This document provides information on First Solar Series 6 *Plus* and Series 6 *Plus* Bifacial modules for system designers, installers, and maintenance personnel.

Modules are intended to be used only by qualified professionals. Modules in the USA are intended to be used exclusively in utility-scale markets. Unintended use of the products may void the warranty and subject you to liability.

The Series 6 *Plus* model types follow the below formats where "XXX" references the module power rating and "A" indicates model types with an anti-reflective coating (ARC) on the front side surface and "B" indicates model types with bifacial technology.

- Series 6 *Plus*: FS-6XXX-P and FS-6XXXA-P
- Series 6 *Plus* Bifacial: FS-6XXX-P-B and FS-6XXXA-P-B

All module types above will be referenced as Series 6 *Plus* modules unless otherwise specified as monofacial or bifacial product. In instances not applicable to both Series 6 *Plus* and Series 6 *Plus Bifacial*, the User Guide will specifically name the product type as necessary.

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. PV modules or systems are not intended to be used in USA residential settings (Residential settings shall mean and refer to any building or structure intended for human habitation).

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

WARNING

Modules should only be installed, operated, maintained or used by qualified personnel for their intended use.

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.

Electrically connected modules with undetected damage, e.g. caused by external impact, carry a higher risk of electric shock and fire hazard. System installation codes and standards require measures for early detection and risk reduction such as insulation monitoring and earth fault protection. See IEC 62548, IEC 60364-7-712 and IEC 63112 for guidance. Local codes apply.

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. Do not remove or modify the label on the module.

The module Rated Power is denoted in the 'XXX' position of the base Model Number format of FS-6XXX-P/FS-6XXX-P-B. (Example: FS-6460A-P/FS-6460A-P-B 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]) and Bifacial Nameplate Irradiance (BNPI[2]).

	RATED POWER[3] (-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)	Icf(A)
STC	420.0	180.4	2.33	218.5	2.54	1500	5.0
BNPI – 15%	429.0	180.4	2.37	218.5	2.59		
BNPI – 20%	431.0	180.4	2.39	218.5	2.61		
STC	425.0	181.5	2.34	218.9	2.54		
BNPI - 15%	434.0	181.5	2.39	218.9	2.59		
BNPI – 20%	436.0	181.5	2.40	218.9	2.60		
STC	430.0	182.6	2.36	219.2	2.54		
BNPI -15%	439.0	182.6	2.40	219.2	2.59		
BNPI – 20%	442.0	182.6	2.42	219.2	2.61		
STC	435.0	183.6	2.37	219.6	2.55		
BNPI - 15%	444.0	183.6	2.42	219.6	2.60		
BNPI – 20%	447.0	183.6	2.43	219.6	2.62		
STC	440.0	184.7	2.38	220.0	2.55		
BNPI - 15%	449.0	184.7	2.43	220.0	2.60		
BNPI – 20%	452.0	184.7	2.44	220.0	2.62		

[1] All ratings at STC (1000W/m2, AM 1.5, 25°C Cell Temperature) ±10%, unless otherwise noted
[2] All ratings at BNPI (1000W/m2 + φ x 135W/m2, φ = 15 -20% ± 5%, AM 1.5, 25°C Cell Temperature) ±10%, unless otherwise noted. BNPI only applies to Series 6 *Plus* Bifacial modules.
[3] Measurement uncertainty applies

STC	445.0	185.7	2.40	220.4	2.56	1500	5.0
BNPI - 15%	454.0	185.7	2.45	220.4	2.61		
BNPI – 20%	457.0	185.7	2.46	220.4	2.63		
STC	450.0	186.8	2.41	221.2	2.57		
BNPI - 15%	459.0	186.8	2.46	221.1	2.62		
BNPI – 20%	462.0	186.8	2.53	221.1	2.64		
STC	455.0	187.8	2.42	222.0	2.58		
BNPI - 15%	464.0	187.8	2.47	222.0	2.63		
BNPI – 20%	467.0	187.8	2.49	222.0	2.70		
STC	460.0	188.8	2.44	222.9	2.59		
BNPI - 15%	469.0	188.8	2.49	222.9	2.64		
BNPI – 20%	472.0	188.8	2.51	222.9	2.66		
STC	465.0	189.8	2.45	223.8	2.60		
BNPI - 15%	474.0	189.8	2.50	223.8	2.65		
BNPI – 20%	478.0	189.8	2.52	223.8	2.67		
STC	470.0	191.1	2.46	224.3	2.61		
BNPI - 15%	479.0	191.1	2.51	224.3	2.66		
BNPI – 20%	483.0	191.1	2.53	224.3	2.68		
STC	475.0	191.5	2.48	224.8	2.61		
BNPI - 15%	485.0	191.5	2.53	224.8	2.66		
BNPI – 20%	488.0	191.5	2.55	224.8	2.68		
STC	480.0	192.8	2.49	225.4	2.62		
BNPI - 15%	490.0	192.8	2.54	225.4	2.67		
BNPI – 20%	493.0	192.8	2.56	225.4	2.69		

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 WIRING SYSTEM DERATING FACTORS

Under normal operation, a PV module may experience conditions that produce higher current and/or voltage than reported at STC. Factors to consider include module temperature and front side irradiance (and ground albedo, row spacing, and installation height for bifacial modules). Accordingly, the values of Isc and Voc listed for STC (or Isc at BSI for bifacial modules) 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 1250 W/m^2, AM1.5 spectrum, and cell temperature of -10°C, multiply the specific model type STC or BNPI listed Voc value by a factor of 1.1. When calculating module Isc at 1250 W/m^2, AM1.5 spectrum, and cell temperature of 75°C, multiply the specific model type STC or BNPI listed Isc value by a factor of 1.27.

The safety factor of 1.25 given for the minimum voltage rating of the components in the example statement above may be modified during the design of a system according to the minimum temperature of the installation location and the temperature coefficient for Voc. The safety factor of 1.25 given for conductor current ratings values for Isc (or Isc at BSI for bifacial modules) may be adjusted based on the maximum values of irradiance incident on the front side of the module (and the rear side for bifacial modules). To this purpose, a full simulation for the specific location and module orientation (and ground albedo, row spacing and installation height for bifacial modules) is required. Further guidance for the choice of a safety factor other than 1.25 is given in the NEC.

As per NEC 690 (A) an acceptable method of calculating Voc is published by Sandia National Laboratories (reference SAND 2004-3535, *Photovoltaic Array Performance Model*). This model uses irradiance and temperature of a given location to forecast expected open circuit Voltages on a project specific basis.

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 green orientation mark corresponds to the side of the module with the positive junction box cable.

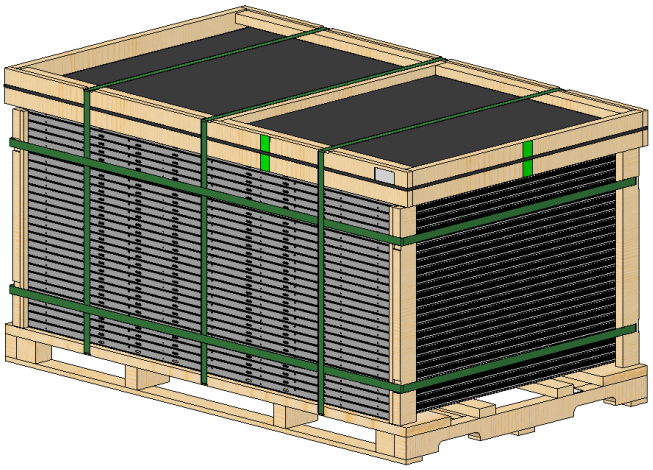


Figure 1: Module Pack Isometric View

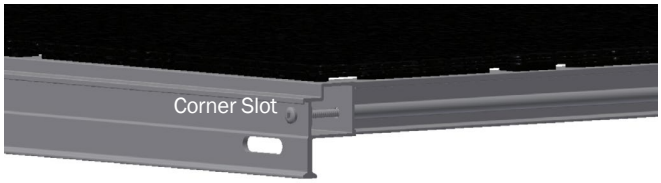


Figure 2: Corner Slot on Long Edge Frame, Isometric View

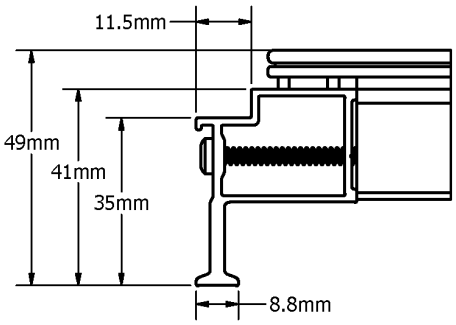


Figure 3: Long Edge Frame Detail

6 MECHANICAL SPECIFICATIONS

Table 3: Series 6 *Plus* Module Mechanical Specifications

SPECIFICATION	Series 6 *Plus* Series 6 *Plus* Bifacial
Module Weight	34.0 kg +1.5/-2.5 kg (75 lbs +3.3/-5.5 lbs)
Top Mount Frame Height	35 mm ± 1 mm (1.38 in ± 0.04 in)
Module/Glass Length	2024/2016 mm +3/-1 mm (79.7 in +0.11/-0.04 in)
Module/Glass Width	1245/1216 mm ± 2 mm (49.0 in ± 0.08 in)
Module/Glass Area	2.52/2.45 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

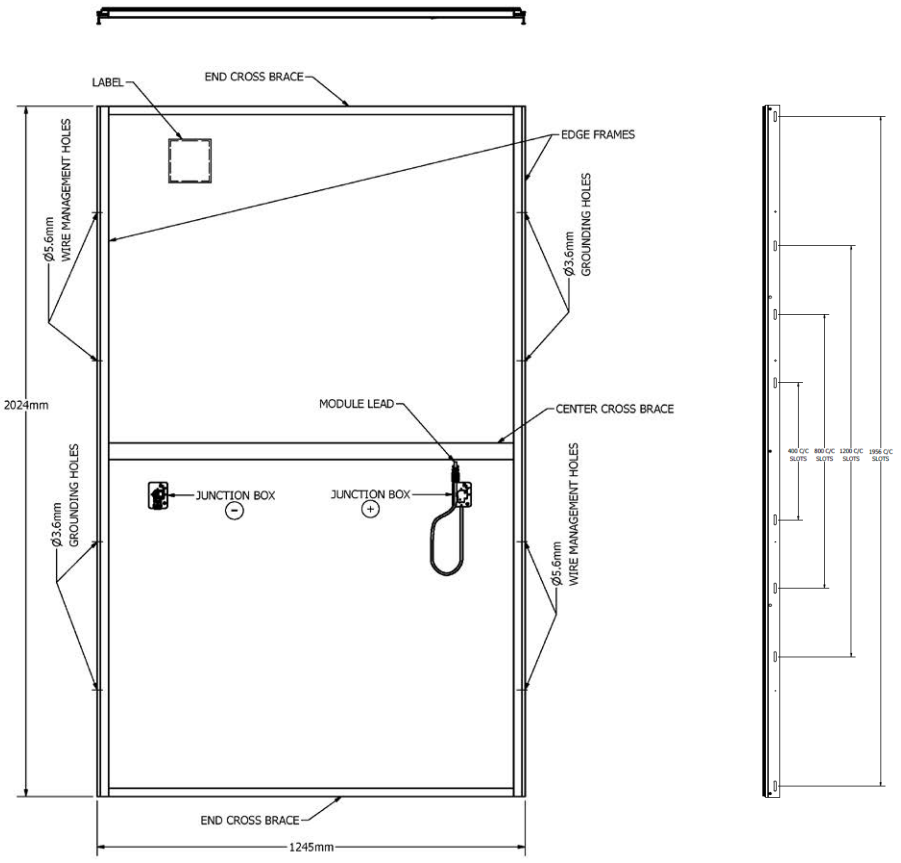


Figure 4: Series 6 *Plus* Module Mechanical Drawing Showing the Backside

[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 and to evaluate the product specifications are suitable for the application environment. 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:

- Modules should only be installed, operated, maintained or used by qualified personnel for their intended use.
- 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 SpeedSlot.

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

Product	Symmetrical Four-point Mount Location	IEC 61215 / IEC 61730		UL 61730	
		Design Load	Test Load	Design Load	Test Load
Series 6 ***Plus*** Series 6 ***Plus*** **Bifacial**	**Top Mount:** Range of 400mm to 1200 mm (C/C) **SpeedSlot Mount:** 400 mm 800 mm 1200 mm	± 1600 Pa (± 33.4 lb/ft^2)	± 2400 Pa (± 50.1 lb/ft^2)	± 1600 Pa (± 33.4 lb/ft^2)	± 2400 Pa (± 50.1 lb/ft^2)
	Corner Slot Mount: 1956 mm	± 800 Pa (± 16.7 lb/ft2)	± 1200 Pa (± 25.1 lb/ft2)	± 800 Pa (± 16.7 lb/ft2)	± 1200 Pa (± 25.1 lb/ft2)

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.

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).

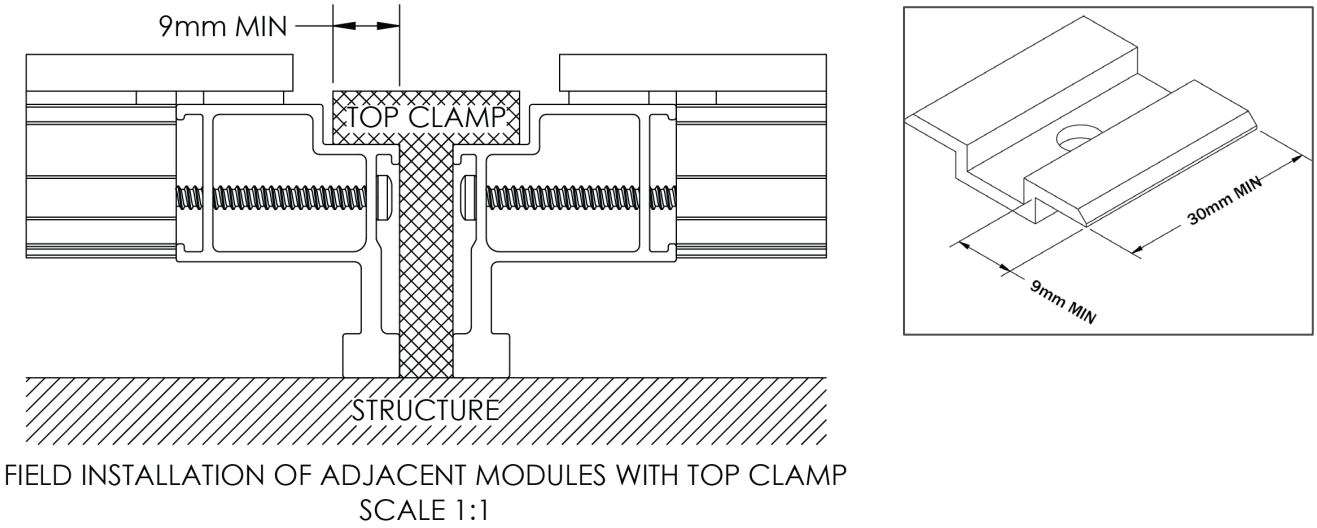


Figure 5: Shared Top Clamp Detail

7.4 SPEEDSLOT MOUNTING

The Series 6 *Plus* module frames include eight SpeedSlot mounting holes 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 hole.

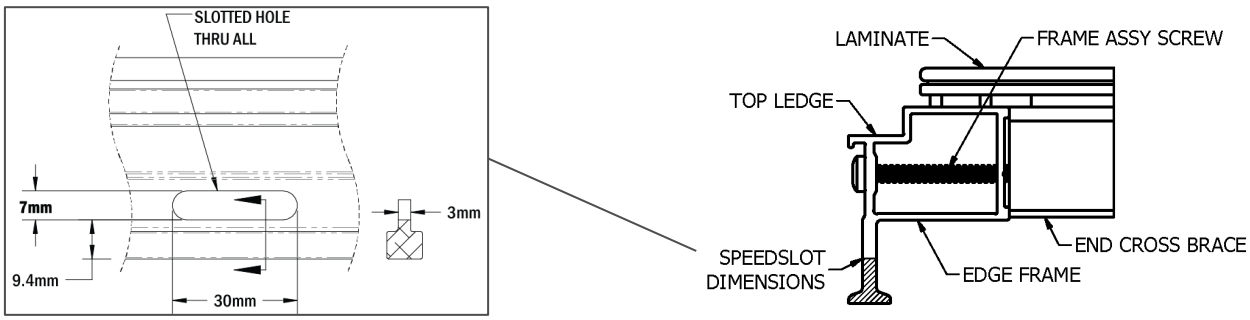


Figure 6: SpeedSlot Hole Dimensions

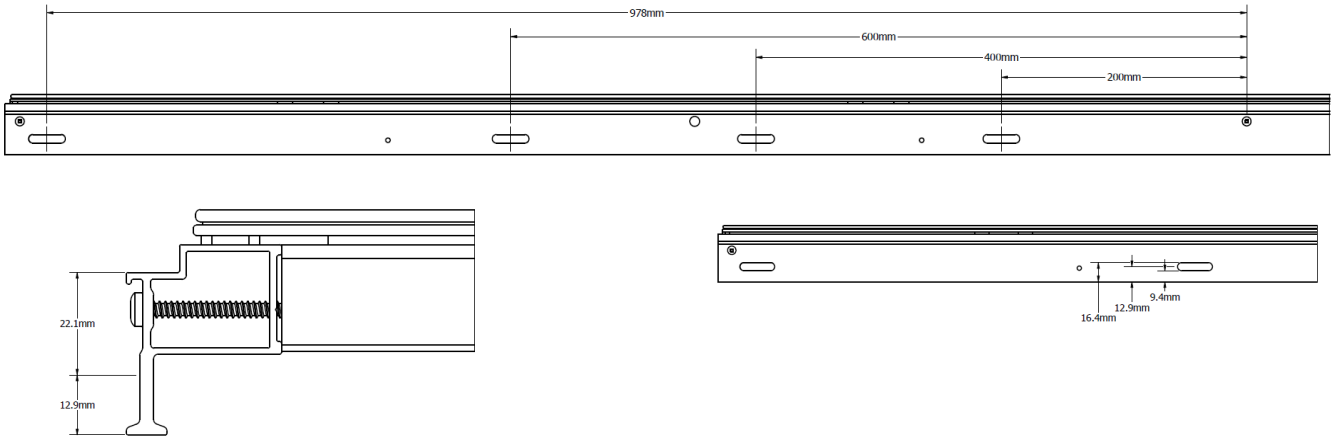


Figure 7: SpeedSlot/Corner Slot hole Detail on Long Edge Frame

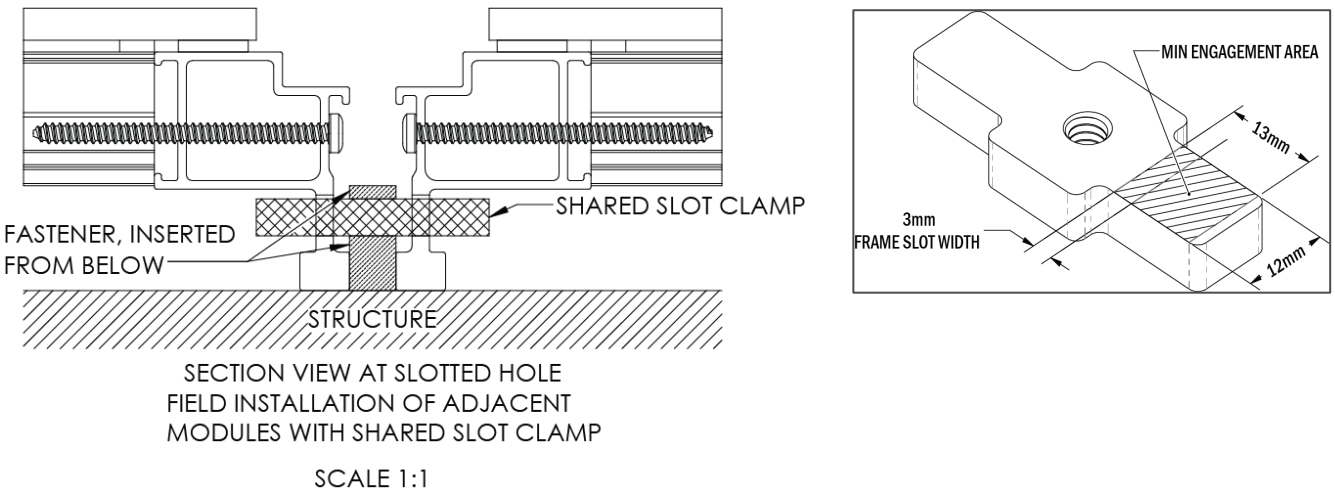


Figure 8: Shared SpeedSlot Clamp Detail

7.5 MODULE ORIENTATION

PV performance modeling software, such as PlantPredict software by Terabase Energy, Inc. (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).

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.

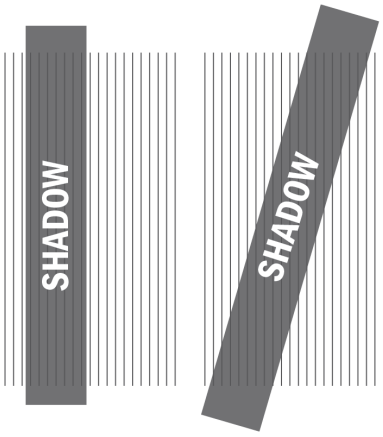


Figure 9: Example of at-risk shading patterns

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).

In the case of Series 6 Plus Bifacial modules, rear side shading is a low risk due to low irradiance levels but should be minimized to promote higher bifacial energy gain.

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 2020
  - 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.

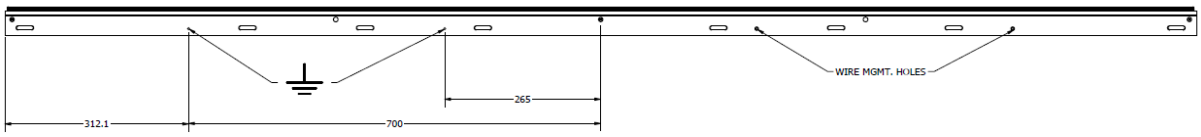


Figure 10: Grounding Hole & Wire Management Hole Detail from Frame Center

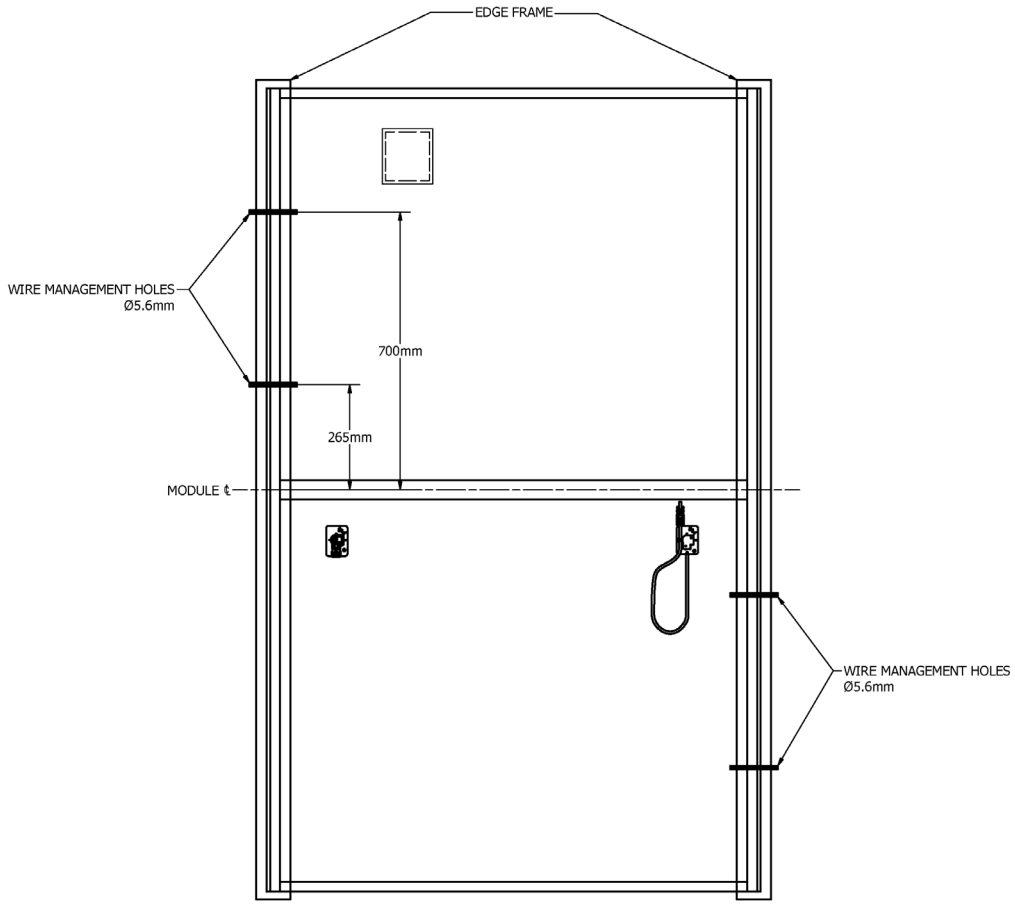


Figure 11: Frame Wire Management Hole Locations

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, tributyl 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.

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. Complete strings of Series 6 *Plus* modules and complete strings of Series 6 *Plus* Bifacial modules can be paralleled for DC collection purposes within the same maximum power point tracker.

It is recommended that individual Series 6 Plus and Series 6 Plus Bifacial modules are not mixed within the same string during the initial installation to minimize electrical mismatch losses. Series 6 Plus and Series 6 Plus Bifacial modules may be mixed within strings for replacement 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

- Functional grounding of conductive non-current carrying parts
  - Typically the grounding can be achieved by mechanical mounting methods or through other methods using the grounding holes provided, in either case the applicable codes and standards, as well as any applicable local requirements determined by local authorities having jurisdiction shall be followed.
  - Utilize marked grounding holes (see Figure 10) 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.

- Functional grounding of one current carrying pole
  - First Solar recommends Series 6 Plus and Series 6 Plus Bifacial 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 negative voltage to ground to demonstrate compliance in event of a future warranty evaluation. Series 6 Plus and Series 6 Plus Bifacial modules must not be used in positive-grounded systems.

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. Rear side appearance differs between monofacial and bifacial modules.

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
2.0	Updated to include Series 6 *Plus SL* and Series 6 *Plus HL*	2/6/2022
2.1	Updated with Corner Slot Images	1/16/2023
2.2	Updated with Corner Slot Load Ratings and Renderings	2/20/2023
2.3	Updated with Safety, Wiring Derating, and Grounding sections, and addition of Bifacial	09/08/2023