User Guide:
FS Series 3 PV Module

North America

REV 3.0

First Solar®

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1 Introduction

First Solar Series 3 PV and Series 3 Black Modules are manufactured in state-of-the-art facilities using a highly innovative process that rapidly deposits thin films of semiconductor on glass. The modules have been designed to have a long operating life and high energy yield—if installed, operated, and serviced in accordance with the instructions in this User Guide as well as in the System Design and Application Document (PD-2-303). First Solar Series 3 and Series 3 Black PV Modules are fully compatible with one another. This User Guide covers both First Solar Series 3 and Series 3 Black PV Modules.

1.1 Before You Begin

This document provides guidelines and information on First Solar FS Series 3 and Series 3 Black PV Modules for system designers, installers, and maintenance personnel. Read this User Guide thoroughly before beginning any work related to the installation, operation, or maintenance of the First Solar Series 3 and Series 3 Black PV Module. Only qualified personnel should install, operate, or maintain a PV module or system.

Failure to follow installation and handling instructions may result in injury.

Failure to maintain proper operating condition requirements for the modules will void the warranty (refer to First Solar FS Series Module Warranty Terms & Conditions PD-5-102).

This guide pertains to modules installed within North America only. If a module is being installed outside of North America, contact First Solar or visit www.firstsolar.com for the User Guide appropriate for other geographic areas.

Keep this User Guide for future reference.

Guidelines related to system construction are beyond the scope of this document and are not covered in this document.

1.2 Key Product Features

- High energy yields in real-world conditions.
- Size and weight that enables efficient handling and installation.
- Easy, quick-connect wiring for fast interconnection.
- Internationally recognized product certifications.
- Ten-year limited material/workmanship and twenty-five year limited power output warranties as outlined in “First Solar FS Series Module Warranty Terms & Conditions” (PD-5-102).

1.3 Safety

WARNING

The FS Series 3 PV and Series 3 Black Modules may produce voltage in excess of 70 Volts DC (VDC) and current in excess of 2.2 Amps when exposed to sunlight. *A single module could create a lethal shock hazard during hours of daylight*, including periods of low light levels. The danger increases as modules are connected together in series and/or parallel.

To avoid fire and/or injury due to ground fault 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 or all modules in series and parallel are covered with an opaque material, such as a tarp or blanket.**
- **Repair or replace 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 open-circuit voltage to exceed 1000VDC under any condition.**
- **Replace broken modules immediately.**
- **Repair any ground faults immediately.**
- **Do not work on modules or systems when the modules or wiring are wet.**

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

- **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.**
- **Comply with all previously noted practices to prevent and repair ground faults.**

Wear safety glasses (ANSI Z87.1-2003) and cut-resistant gloves when working on non-interconnected modules or systems.

Wear electrically rated PPE when working on interconnected modules or system components.

2 Regulatory Compliance

It is the responsibility of the installer and/or system integrator to ensure compliance with all local electrical codes which may be applicable to the installation and use of First Solar Series 3 and Series 3 Black PV Modules.

- Before beginning the PV system design and installation, contact appropriate local authorities to determine local code, permit, and inspection requirements.
- In the United States, refer to Article 690 of the National Electrical Code (NEC) which applies to “Photovoltaic Systems.”
- For systems installed in Canada, installation shall be in accordance with CSA C22.1, Safety Standard for Electrical Installations, Canadian Electrical Code, Part 1.

First Solar FS Series 3 and Series 3 Black PV Modules are Listed by a Nationally Recognized Test Laboratory to UL 1703, 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 1000VDC.
- Install modules with mounting systems that have been evaluated for UL Listed application as specified in First Solar Application Note PD-5-320 NA.
- Protect modules from reverse currents in excess of the Maximum Series Fuse rating of 3.5A as specified in First Solar Application Note PD-5-308.

FS Series 3 and Series 3 Black PV Modules meet the requirements of Safety Class II and are tested and certified per IEC 61730 Application Class A for a maximum system voltage of 1000V with maximum overcurrent protection rating of 3.5A.

FS Series 3 and Series 3 Black PV Modules are tested and certified per IEC 61646 for a maximum system voltage of 1000V.

3 Electrical Specifications

MODEL NUMBERS AND RATINGS AT STC*							
Nominal Values		FS-382	FS-385	FS-387	FS-390	FS-392	FS-395
Nominal Power (±5%)	P_{MPP}(W)	82.5	85.0	87.5	90.0	92.5	95.0
Voltage at P_{MAX}	V_{MPP}(V)	48.3	46.4	47.0	47.4	47.7	47.5
Current at P_{MAX}	I_{MPP}(A)	1.71	1.83	1.83	1.90	1.94	2.00
Open Circuit Voltage	V_{OC}(V)	60.8	60.5	60.5	60.5	60.5	60.5
Short Circuit Current	I_{SC}(A)	1.94	1.94	1.99	2.06	2.11	2.17
Maximum System Voltage	V_{SYS}(V)	1000					
Maximum Series Fuse	I_{CF}(A)	3.5					

* As received and stabilized ratings at Standard Test Condition (1000W/m^2, AM 1.5 25°C Cell Temperature) +/-10%

Electrical specifications are subject to change. See the module label for additional electrical ratings.

3.1 System Derating Factors

Under normal conditions, a photovoltaic module may experience conditions that produce more current and/or more voltage than reported at Standard Test Conditions. Accordingly, when determining component ratings, the values listed for open circuit voltage should be multiplied by a calculated factor based on the low temperature open circuit voltage temperature coefficient. Refer to First Solar Application Note PD-5-435 for additional information on the calculation of this voltage multiplication factor. Values listed for current should be multiplied by 1.25. Refer to Section 690-8 of the National Electrical Code for an additional multiplying factor of 125 percent (80 percent derating) which may be applicable in computation of maximum circuit current for proper conductor sizing. Adjustments of those factors might be needed to respect site specific climate conditions.

4 Installation

4.1 Mounting

Physically damaged modules may cause ground faults and associated electrical hazards. To avoid these conditions:

- **Handle modules with care during installation, as heavy impact on the front, back, or edges could result in damage to the module. Do not walk or stand on modules.**
- **Do not stack or carry multiple modules on top of one another after removal from factory packaging to minimize the risk of breakage.**
- **Do not lift or pull on modules using lead wires or strain relief wire loops to minimize the risk of wire damage.**

Do not install the modules in high wind or wet conditions to reduce the likelihood of injury.

Wear safety glasses (ANSI Z87.1-2003) and cut-resistant gloves when working on non-interconnected modules or systems.

Wear electrically rated PPE when working on interconnected modules or system components.

Mounting of the FS Series 3 and Series 3 Black PV Module to a suitable structure can be done by attaching the module directly to the structure using retaining clips (see Figure 5.1).

The module is considered to be in compliance with UL 1703 only when the module is mounted in the manner specified by the mounting instructions specified in First Solar Application Note PD-5-320 NA.

Any module without a frame (laminate) shall not be considered to comply with the requirements of UL 1703 unless the module is mounted with hardware that has been tested and evaluated with the module under this standard or by a field Inspection certifying that the installed module complies with the requirements of UL 1703. The FS Series 3 and Series 3 Black PV module is a frameless laminate and is considered to be in compliance with UL 1703 only when the module is mounted using approved hardware in the manner specified by the mounting instructions in First Solar Application Note PD-5-320 NA.

Additional mounting systems may be approved for use. Retaining clip designs must meet the technical requirements specified in First Solar Application Note PD-5-320, and must be approved for use by First Solar prior to installation. The mounting system design must provide adequate support for the glass laminate module to prevent damage from occurring when the module is subjected to wind loads of 130km/h (80.8 mph), with a safety factor of 3 for gusty conditions. The location of the clips shall be along the 1200mm (47.25 in) length of the module and the center point of the clip shall be located between 250mm (9.84 in) and 300mm (11.81 in) from the module edge. See Figure 5.1 for allowed location. Rubber gasket material, or equivalent, must be used between the module and both the clip and mounting structure to provide adequate protection of the glass laminate module. No direct contact of rigid structures is permitted against the surface or edges of the glass laminate.

All mounting structures must provide a flat plane for the modules to be mounted on, and must not cause any twist or stress to be placed on the module.

Modules should not be installed in a way that restricts air circulation to the backside of the module. Modules generate heat and require adequate airflow for cooling.

Installation locations and module support structures should be selected to ensure modules and connectors (open or mated) are never submersed in standing water. First Solar modules are tested and certified for applications involving pressures from snow/ice/wind up to 2400 Pa (50.13 lb/ft2) when mounted properly. Snow drifts could result in a nonuniform loading of the modules which exceeds the tested pressure. If it is expected that loads will exceed 2400 Pa (50.13 lb/ft2), it is recommended to clear snow from modules, and ensure that ice/thaw/freeze cycles under snow drifts do not result in excessive stresses on the module.

Heavy construction and trenching should be completed prior to module installation to minimize debris and dust.

Ensure any soil binding agents or salts used for on-site dust control do not spray, splash, or drift onto the surface of the modules.

The UL approved design load of FS Series 3 and Series 3 Black PV Modules is 30 lb/ft2 (1436 Pa).

Maximum allowable pressure on modules may not exceed 2400 Pa (50.13 lb/ft2) without additional module support that must be tested and approved by First Solar.

For rooftop mounting, modules must be mounted over a fire resistant roof covering rated for the application. The recommended minimum standoff height is 3.25 in (82.55 mm). Modules used in UL Listed rooftop applications must be installed with approved mounting systems as specified in First Solar Application Note PD-5-320 NA. If alternate mounting means are employed, this may affect the Listing fire class ratings. The fire rating of this module is valid only when mounted in the manner specified in the mechanical mounting instructions.

4.2 Location, Angle and Tilt

To maximize performance, modules should be located in an area that receives direct sunlight from mid-morning to midafternoon (typically 9:00 a.m. to 3:00 p.m.). Installation must avoid locating the modules where shadows may be caused by buildings, trees, etc.

PV performance modeling software should be used to determine the optimum orientation and tilt angle for each location.

For tilted free-field applications where there is row to row shading, it is required to install the modules in landscape orientation. Please refer to First Solar Application Note PD-5-425-03 for additional information.

4.3 Module Shading Considerations

To minimize the risk of module shading damage please follow the Module Shading Field Guide PD-5-366. Instances of shading that will lead to a voided warranty include the High Risk listed items below.

High Risk (Prohibited) Shading

1. Resting or adhering slender objects (tools, brooms, clothing, wires, tape) on sunny side of operating modules, or within inches above operating modules, especially when shadow oriented parallel to cells, can create high risk of undesirable shading.

2. Fixed objects within ~5-7 feet above operating modules that cast a shadow over the long dimension of the cell should be avoided. Close objects like posts, ropes, signs, fences, or equipment can begin to increase risk of partial shading of full cells when nearer than ~5-7 feet from the sunny-side of operating module.
3. Working continuously with outstretched arms or tools over operating modules can create high risk of undesirable shading.
4. A support frame or mounting method on the short edge(s) of modules that fully shades the entire length of a cell (either partially or completely) can create a high risk of undesirable shading.
5. Cleaning apparatuses, including cleaning robots and other mechanisms that traverse the module repeatedly while the system is operating (unless evaluated and approved by First Solar).

4.4 Electrical Interconnection

First Solar FS Series 3 and Series 3 Black PV 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 connectors are UV and weather resistant from –40°C to +90°C, and rated for 1000VDC and 30A (minimum, before derating for ambient temperature).

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 lead wires tight at any time. After installation, the connected wire must not be under stress or tension.**
- **Do not use junction box assembly or lead wire strain relief loops to secure excess wire or to bear weight in excess of a module’s own wire and mated connector pair.**
- **Connector bodies and cables should not be tightly secured at both ends to any mounting structure to allow for thermal expansion and contraction.**
- **Secure wire or connected components so that no loose wires or components are hanging within 1.5 feet (0.46m) of the ground in free field applications, and so that wire/components are hanging clear of roof coverings or pooled water in rooftop applications.**
- **Ensure connectors are fully mated.**
- **Ensure wire securement methods, such as use of cable ties, do not damage wire insulation. The minimum module lead wire bend radius is 5 times wire diameter. Observe minimum bend radius specifications on all other PV system wiring.**
- **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.**

Modules with different FS Series numbers (i.e. FS 2 vs. FS 3) have significantly different electrical operating characteristics and should not be interconnected within the same inverter to prevent power output loss and voltage imbalance conditions that may create the risk of reverse current overload.

FS Series 3 and Series 3 Black modules are electrically compatible, but may vary in module connector type. Certain certifying bodies may not certify interconnection of these different connector types. In these cases, module-module and module-harness connections must either be like for like suppliers or adapter cable connections would be needed.

Module to module and module to harness interconnection is advised to be done between same manufacturer and type of connectors. The First Solar module warranty is not affected by the interconnection of different supplier connectors, however, First Solar cannot guarantee that different connector types will be mateable in every connection instance.

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

When connecting First Solar FS Series 3 and/or Series 3 Black PV Modules in a series string, ensure that the system design voltage limit is not exceeded. For 1000VDC applications, this is typically ensured by limiting series strings to 15 modules or less.

FS Series 3 and Series 3 Black PV Modules are designed for interconnection with grid-tie PV inverters. For off-grid applications, modules must be coupled with maximum power point tracking (MPPT) charge controllers or otherwise maintained at their maximum power point. All inverters must meet the technical requirements specified in First Solar Application Note PD-5-310 and must be approved for module compatibility by First Solar prior to installation. When connecting modules or module strings in series ensure inverter ratings are appropriate.

Open circuit exposure may accelerate module efficiency loss and should therefore be minimized. First Solar requires that modules not be operated in open circuit conditions for more than ninety (90) cumulative days to avoid a potential reduction in energy output over the life of the modules.

Modules must not be operated under short circuit conditions for extended durations. Short circuit operation is not an approved mitigation technique for open circuit exposure.

4.4.1 Grounding Method

Per the requirements of UL 1703, a module with exposed conductive parts is considered to be in compliance with UL 1703 only when it is electrically grounded in accordance with the instructions presented and the requirements of the National Electrical Code.

First Solar FS Series 3 and Series 3 Black PV Modules have no exposed conductive surfaces and do not require equipment grounding as long as a clip length of 100mm for a standard 4 clip mounting is not exceeded. In the U.S., the mounting structure must be grounded per the requirements of the NEC, sections 250 and 690.

First Solar recommends negative pole DC electrical system grounding for large utility scale systems.

4.4.2 Overcurrent Protection

FS Series 3 and Series 3 Black modules have a maximum series fuse rating of 3.5A as defined by UL 1703 test methods.

FS Series 3 and Series 3 Black modules have a maximum overcurrent protection rating of 3.5A as defined by IEC 61730 test methods.

PV systems should be designed to comply with and provide module overcurrent protection consistent with local codes as appropriate for the intended application class of the system.

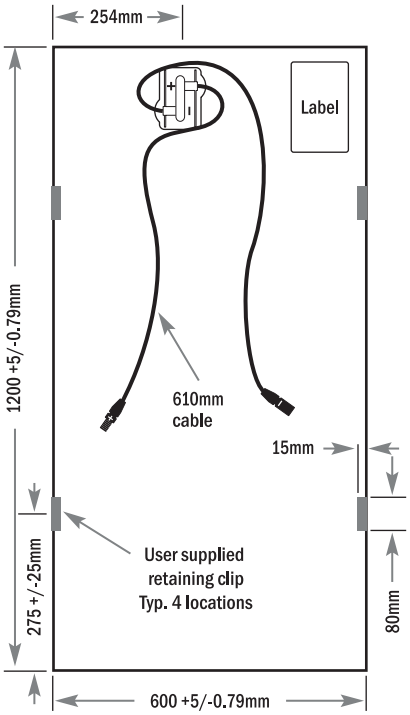
Please refer to FS Application Note PD-5-308 for additional information on module overcurrent protection.

5 Mechanical Specifications & Drawings

Table 5.1: Mechanical Specifications

Specifications	FS Series 3 and Series 3 Black PV Module	
Length	1200 mm	47.25 in
Width	600 mm	23.63 in
Thickness	6.8 mm	0.27 in
Area (total aperture)	0.72 m^2	7.75 ft^2
Weight	12 kg	26.5 lbs
Fire Rating	Class B (Class A Spread of Flame)	
Operating Temperature	-40°C to +85°C	

Figure 5.1 Mechanical Drawing for FS Series 3 and Series 3 Black PV Modules



6 Proper Operating Conditions

The proper operating condition requirements listed below must be maintained.

Important: **Failure to maintain proper operating condition requirements for the modules will void the warranty (refer to First Solar FS Series Module Warranty Terms & Conditions PD-5-102).**

Requirements:

- First Solar requires installers to use commercially reasonable efforts to grid-connect the modules as soon as practicable to prevent open circuit exposure or to use mitigation techniques (resistive load banks) to maintain conditions equivalent to normal loaded maximum power point (MPP) operation. First Solar must be notified in writing prior to exceeding 90 days of cumulative module operation in open circuit conditions. Upon conclusion of open circuit exposure, this notification must be supplemented to report total time in open circuit on a per inverter basis. Failure to complete this notification in a timely manner may void module warranty coverage at the election of First Solar. First Solar reserves the right to modify module power output warranty coverage in the event 90 day open circuit exposure is exceeded.
- Short circuit operation is permitted only during short duration system safety testing or in failsafe system states.
- All electronic components that are interconnected to modules must have an operating voltage window that matches the maximum power point of the array, and be capable of operating the array at the maximum power point at all times.
- All electronic components that are interconnected to modules must be rated for the maximum operating voltage of the array.
- Modules must have adequate ventilation and airflow to prevent excessive operating temperatures above 85 degrees C.
- Modules must not be partially shaded by obstructions at times of high irradiance (typically between 9:00am and 3:00pm). Module row-to-row shading in landscape orientation is acceptable; Module row-to-row shading in portrait orientation is prohibited.
- Modules must not be used in positive-grounded or bi-polar systems.
- Strain relief cable ties must not be removed.
- If module cleaning is undertaken, modules must be cleaned only when in open circuit – either disconnected from load, or during times when inverter is turned off and otherwise in accordance with PD-5-804 “FS Series PV Module Cleaning Guidelines”.

7 Service

- Periodically, annually at a minimum, inspect modules for any signs of damage or broken glass.
- Broken modules should be replaced immediately. If broken modules are found, place material into a closed container for return to First Solar module recycling program. Please visit www.firstsolar.com/recycling for further details on the recycling program.
- Check that all electrical connections are tight and corrosion free.
- Large amounts of dust and dirt on the surface of the module can reduce the power produced. Natural rainfall will typically remove most dust. Should auxiliary cleaning be required, please refer to “FS Series PV Module Cleaning Guidelines” (PD-5-804) for additional information.

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

- 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
- Improperly calibrated or malfunctioning monitoring equipment

8 Warranty Terms & Conditions

Please refer to, “First Solar FS Series Module Warranty Terms & Conditions” (PD-5-102) for warranty terms, limitations, and product return policies.

9 Notice

Changes to certain components of the module are common as First Solar continuously strives for product improvements. Changes may be a result of component improvements or changes by a supplier, or by minor design modifications initiated by First Solar. All products within the same model classification remain functionally equivalent and fully compatible with one another, even though there may be slight differences. Modifications that do not impact the functionality of the product will typically be made without customer notification. Internal testing, and review or retesting by a certifying agency, will be completed before component or design changes are introduced into the manufacturing process.

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.

In the event of a conflict between this module User Guide and the instructions of one of the system component manufacturers, the system component instructions should prevail.

For information regarding First Solar and its products, please visit www.firstsolar.com. For technical support, please contact technicalsupport@firstsolar.com.

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10 Revision History

Revision Number	Amendment Detail	Revision Date
1.0	Table typo corrected.	9/12/2010
1.1	Series table typo corrected.	1/4/2011
1.2	Updated electrical specification table to reference FS-372 through FS-382.	2/14/2011
1.3	Updated to PDF format. Updated electrical specification table to reference FS-375 through FS-385.	10/14/2011
1.4	Update to workmanship warranty.	12/16/2011
2.0	Updated to PDF format. Updated electrical specification table to reference FS-377 through FS-390.	1/13/2012
2.1	Updated to PDF format. Updated electrical specification table to reference FS-380 through FS-392.	10/24/2012
3.0	Updated to include Series 3 Black verbiage. Updated to PDF format. Updated electrical specification table to reference FS-382 through FS-395. Module Shading Considerations Section added. Connector interconnection comments added. Recycling verbiage update. Revision History added and replaced Appendix.	4/23/2013