Asia-Pacific Economic Cooperation

Rooftop Solar PV System Designers and Installers

Training Curriculum

APEC Secretariat

March 2015


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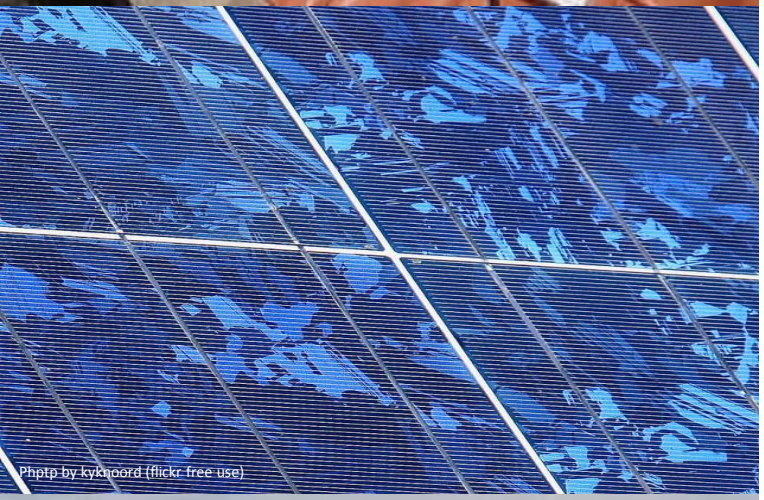
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BRAND SPECIFIC PROCEDURES

Training of PV Designer and Installer

APEC
Asia-Pacific Economic Cooperation

Cu International Copper Association
Copper Alliance

castlerock consulting

Contents:

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A. Introduction

B. SMA – Sunny Island
   - Mounting procedure
   - Electrical connection procedures
   - Application

C. SMA – Sunny Boy
   - Mounting procedure
   - Electrical connection procedures
   - Application

D. Outback Inverter and Charge Controller

E. Solar PV Module Mounting

Note to Training Institution

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If SMA and Outback are not easily available in the marketplace, this training material should be supplemented with a summary of the instruction manual of the brands available locally

SMA and Outback represents two brands that have comprehensive manuals that can be used as a benchmark of industry accepted best practices

Introduction

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This part of the training is to introduce common installation procedures as required by major solar PV component makers. Most of the recommendations and requirements can be used on other brands as an industry accepted bet practices

Not every page of the installation manual is reproduced here, each participant is encouraged to read and understand the complete documentation. In addition, if these brands are not easily available in the area, the installation manual of the components to be installed MUST be read in full and understood

SMA Sunny Island

A battery based inverter/charger, also called a bi-directional inverter

In residential grid tied system, an SMA Sunny Island inverter is used to store excess energy to a battery system and to use the batteries to reduce the grid power requirement

SMA – Distribution Room

- Dry, well-lighted room.
- Make sure that there is free access to the distribution system
- Ideally is a dedicated room for the solar PV system components that includes space for the inverters

- Make sure that there is sufficient ventilation for air circulation (specifically when using flooded lead acid batteries) and temperature regulation

SMA - Inverter

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General requirement

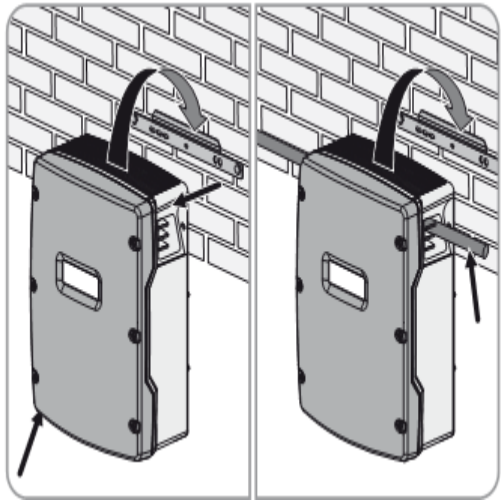
- Inverter and PV module should be installed as close as possible
- Inverter to be mounted on a solid foundation
- Mounting on a flammable foundation (e.g. wood) is not allowed
- The mounting location must be suitable for the weight and dimensions of the components
- The mounting location must not hinder access to disconnection devices and maintenance/service procedures
- Eye level mounting provides optimal readability of the device's operational indicators or display
- Open space is also important above and — depending upon the device type — next to the devices to ensure proper heat dissipation and good ventilation

SMA – Sunny Island

- **Inverter/ charger**
  - The mounting location must not be exposed to direct solar irradiation. Direct solar irradiation can cause the Sunny Island to overheat
  - The mounting location must be below 3,000 m above MSL. For altitudes of 2,000 m above MSL, the power is reduced by 0.5% per every 100 m
  - The ambient temperature should be below 40°C. This will ensure optimum operation of the Sunny Island

Mounting procedures:

1. Use at least one hole on the right-hand and left-hand side in the wall mounting bracket
2. Ensure that there are no electric lines or other supply line sin the wall behind the marked positions



SMA – Sunny Island: Electrical connection procedures

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1. Calculate the cross-section of the grounding conductor
   - The required cross-section of the grounding conductor can be calculated using the following formula:

$$S_{Cu}(I, t) = \sqrt{\frac{I_{SC} \cdot t}{143}}$$

S_{Cu} = conductor cross-section in mm²

I_{SC} = short-circuit current in A

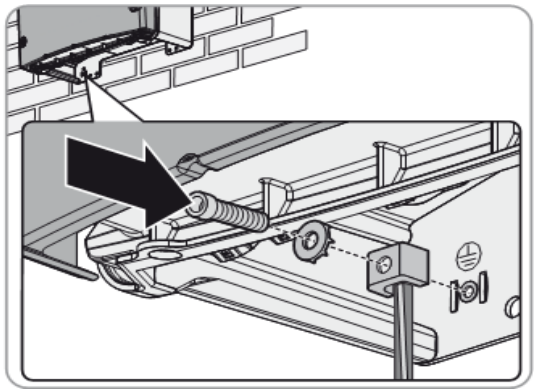
t = interruption time in s

   - Typical tripping times for an LV/HRC fuse is around 25 ms for short-circuit currents between 2,000 A and 10,000 A. Grounding with a cross-section of 16 mm² (copper wire) is sufficient for short-circuit currents up to 10,000 A
2. Ensure that there are no electric lines or other supply lines in the wall behind the marked positions

SMA – Sunny Island: Electrical connection procedures

Asia-Pacific Economic Cooperation

3. Fasten the clamping bracket using a M6x16 hexagon socket screw and a conical spring washer (AW 5, torque: 4 Nm to 5.7 Nm). The teeth of the conical spring washer must face the clamping bracket



4.Cable length and recommended conductor cross-section for the DC connection can be seen in the table below

Long cables and insufficient conductor cross-sections reduce the efficiency of the system and the overload capacity of the Sunny Island. The maximum cable length from the battery to the Sunny Island is 10 m

Sunny Island	Cable length	Conductor cross-section
SI 8.0H	≤ 5 m	70 mm²
	> 5 m	95 mm²
SI 6.0H	≤ 5 m	50 mm²
	> 5 m	70 mm²

SMA – Sunny Island: Electrical connection procedures

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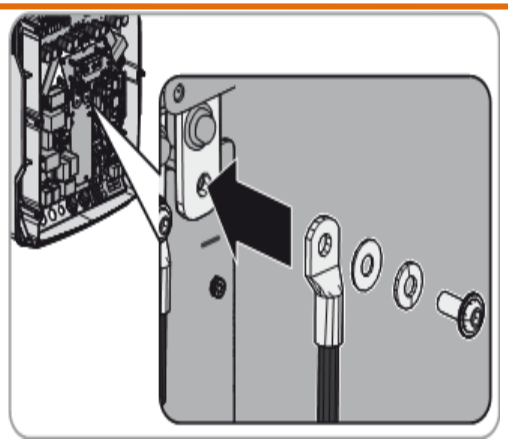
5. Fasten the DC power cables to the DC terminal with M8x20 screws, ensuring correct polarity (torque: 12 Nm). Make sure that the cable is correctly connected



Damage to the Sunny Island due to reverse polarity or wrong choice of terminal lug!

6. Connecting to Sunny Remote Control with the following requirement:
   - Maximum cable length: maximum 20 m
   - Classification: CAT5e
   - Type of plug: RJ45
7. Connecting the AC Power Cable requirements:
   - Copper wire cable
   - Cable diameter: 9 mm to 18 mm

SMA – Sunny Island: Checking the wiring

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Ensure that you carry out all tests relevant to the system and rectify all detected problems. Sunny Island inverters must be disconnected from all voltage sources

1. Checking the Grounding

   - Grounding conductor connection to ground

     The grounding conductor must be grounded, e.g. by connection to a grounding busbar or a foundation ground electrode

   - With a TN system, neutral conductor and grounding conductor connection

     Ensure by measuring that there is a conductive connection between the neutral conductor and the grounding conductor

SMA – Sunny Island: Checking the wiring

Asia-Pacific Economic Cooperation

2. Checking the DC Connection

- DC connection

Terminal lugs are firmly fastened on the Sunny Island (torque: 12 Nm)

- DC power cable

The conductor cross-section corresponds to the minimum requirements of 50 mm² to 95 mm²

- BatFuse (an SMA accessory that should be included in every Sunny Island installation)

Fuse links are matched to the Sunny Island.

- SI 8.0H: 200 A
- SI 6.0H: 160 A

SMA – Sunny Island: Checking the wiring

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3. Checking the AC1 and AC2 terminals

- AC1 and AC2 terminals

  All terminal levers are in the downward position and all cables are securely clamped.

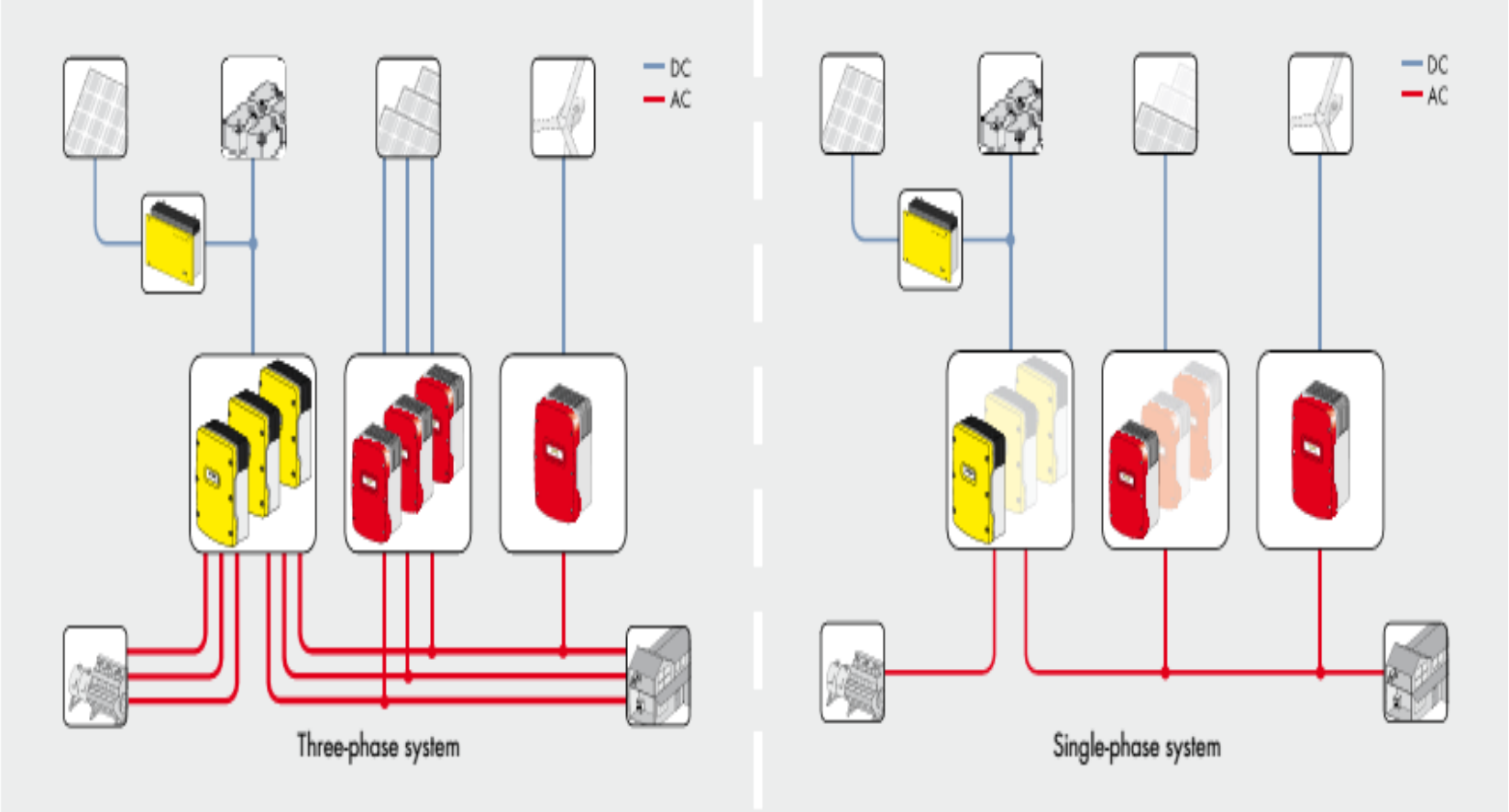
- AC power cable

  The cables are sufficiently protected by circuit breakers with tripping characteristics B16 or C6 are installed or additional residual-current devices have been installed.

- With a three-phase system

  The master must be assigned to L1, slave 1 must be assigned to L2, slave 2 must be assigned to L3.

SMA – Sunny Island: Application



SMA Sunny Boy/TriPower

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A grid inverter, Sunny Boy models are one-phase inverters whereas TriPower models are three-phase inverters

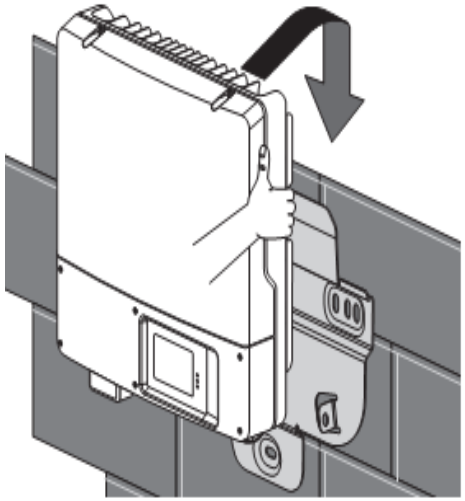
Used to change the DC electricity from the solar panels to the AC power matching the grid's voltage and frequency

SMA – Sunny Boy (Grid-tie inverter)

- Usually SMA grid-tie inverter (or mostly called PV inverter) is suitable for indoor and outdoor use
- When exposed to sunlight, the PV array generates a dangerous DC voltage which is present in the DC conductors or the live components in the inverter
- Before starting work on the PV array, always disconnect the inverter on the AC and DC sides
- When disconnecting the DC connectors from the inverter under load, an electric arc may occur, causing electric shock and burns

Mounting procedures:

1. Use at least one hole on the right-hand and left-hand side in the wall mounting bracket
2. Ensure that there are no electric lines or other supply lines in the wall behind the marked positions



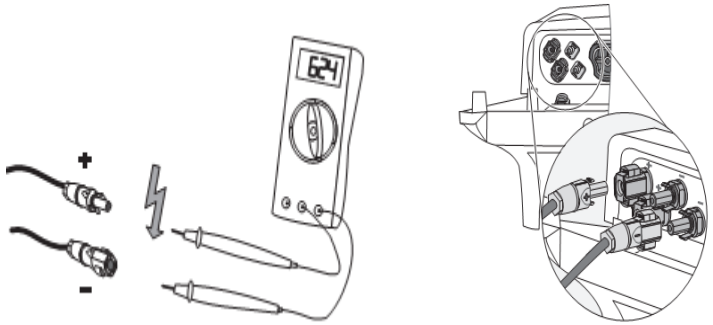
SMA – Sunny Boy: Electrical connection procedures

1. Connecting the PV Array (DC)

- The connection cables of the PV modules must be equipped with connectors
- At the DC input of the inverter, the following limits must notbe exceeded:

Maximum input voltage	Maximum input current
750 V (DC)	15.0 A (DC)

- Check the connection cable of the PV modules for correct polarity and make sure that the maximum input voltage of the inverter is not exceeded



- Check the DC connectors for correct polarity and connect them.

SMA – Sunny Boy: Electrical connection procedures

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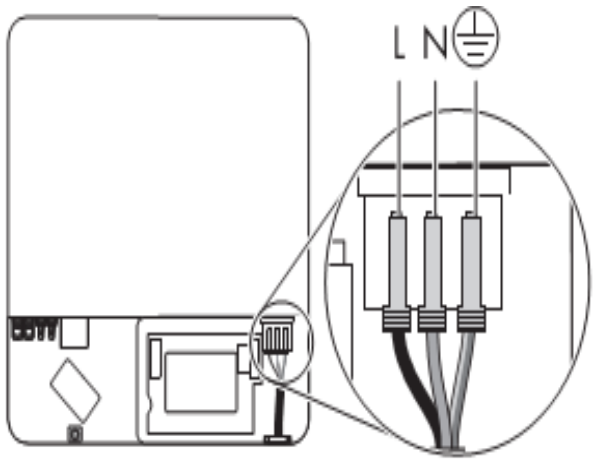
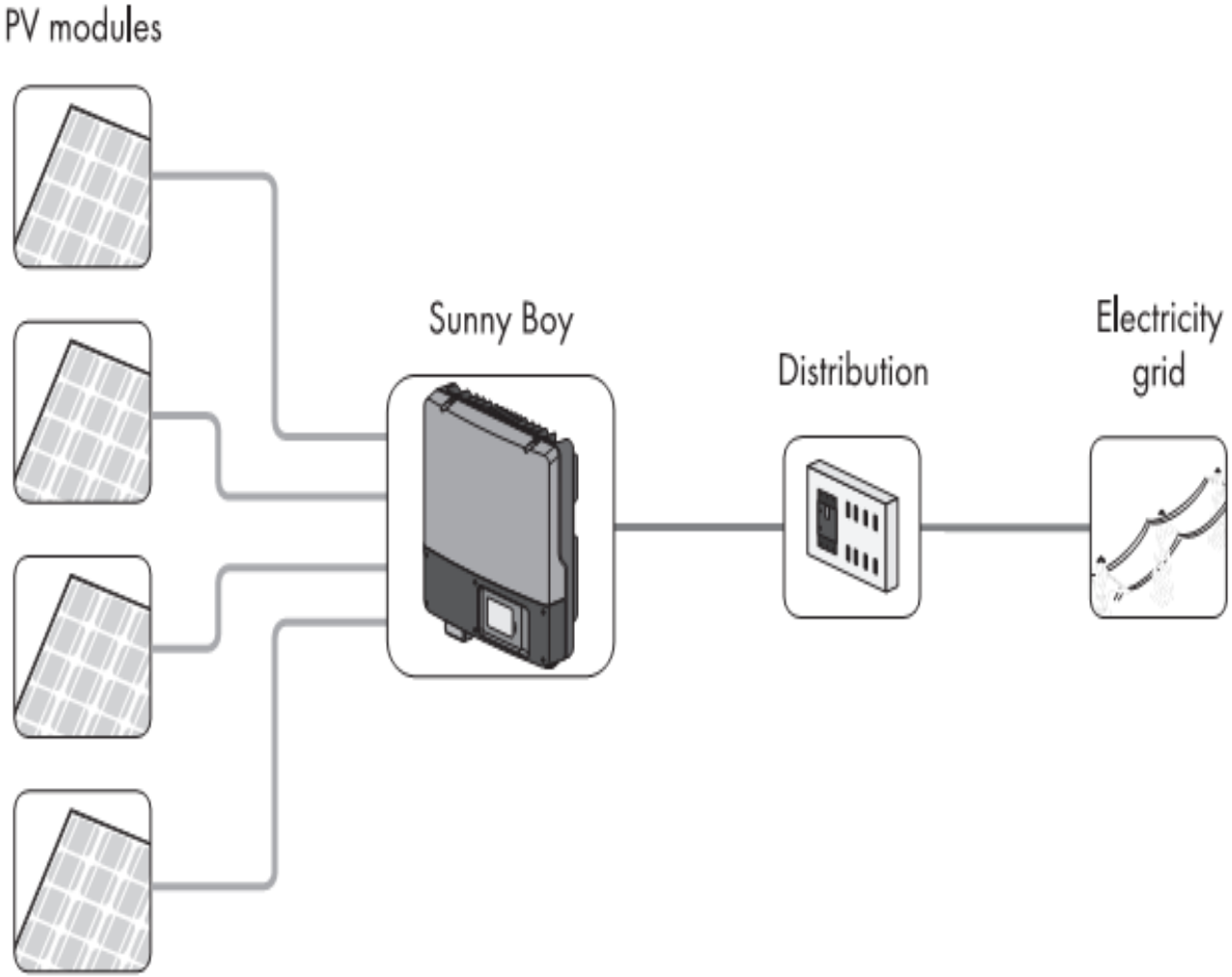
2. Connecting the Inverter to the Electricity Mains (AC)
   - Make sure that the mains voltage is within the permissible voltage range
   - Shut down the miniature circuit-breaker and secure it to prevent reactivation
   - Check that the country setting of the inverter is correct using the supplementary sheet with the default settings provided.
   - NOTICE!
   - Risk of fire when connecting two conductors to a single terminal
   - Connect L, N and the protective conductor (PE) to the AC terminal in accordance with the label.
   - L and N must not be swapped.



SMA – Sunny Boy: Application



Outback DC Coupled System

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Consists of a Solar Charge Controller (FlexMax FM60 and FM80 models) and a battery based inverter/charger (Radian and FX models)

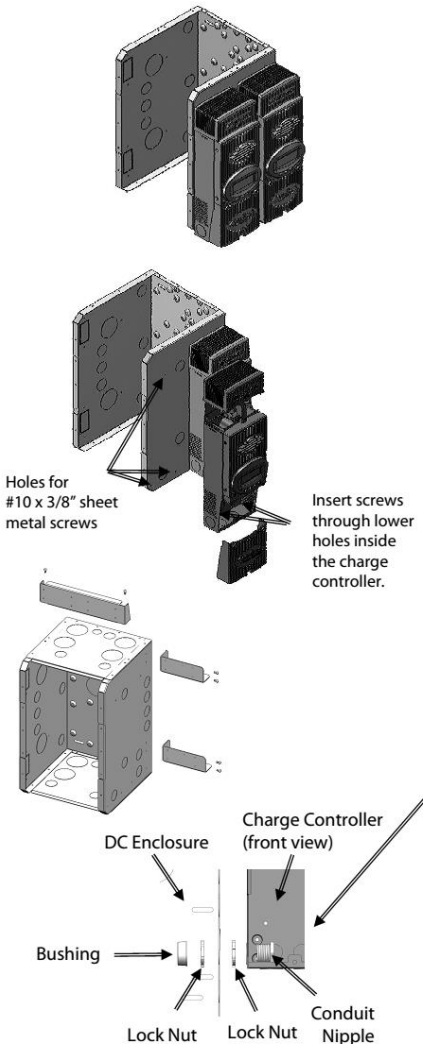
Outback – Flexmax: Application

Mounting directly to a FLEXware DC enclosure:

1. Remove the fan cover and bottom cover from the FLEXmax.
2. 2. Insert a #10 X 3/8” sheet metal screw in the top hole on the side of the DC enclosure. This will act as a hanging screw for the keyhole slot at the top center of the FLEXmax.
3. 3. Hang the FLEXmax on the top screw and line up its bottom two screw holes with the holes on the enclosure.
4. 4. Insert a #10 x 3/8” sheet metal screw through each hole and tighten against the enclosure (screws are included with each DC enclosure).

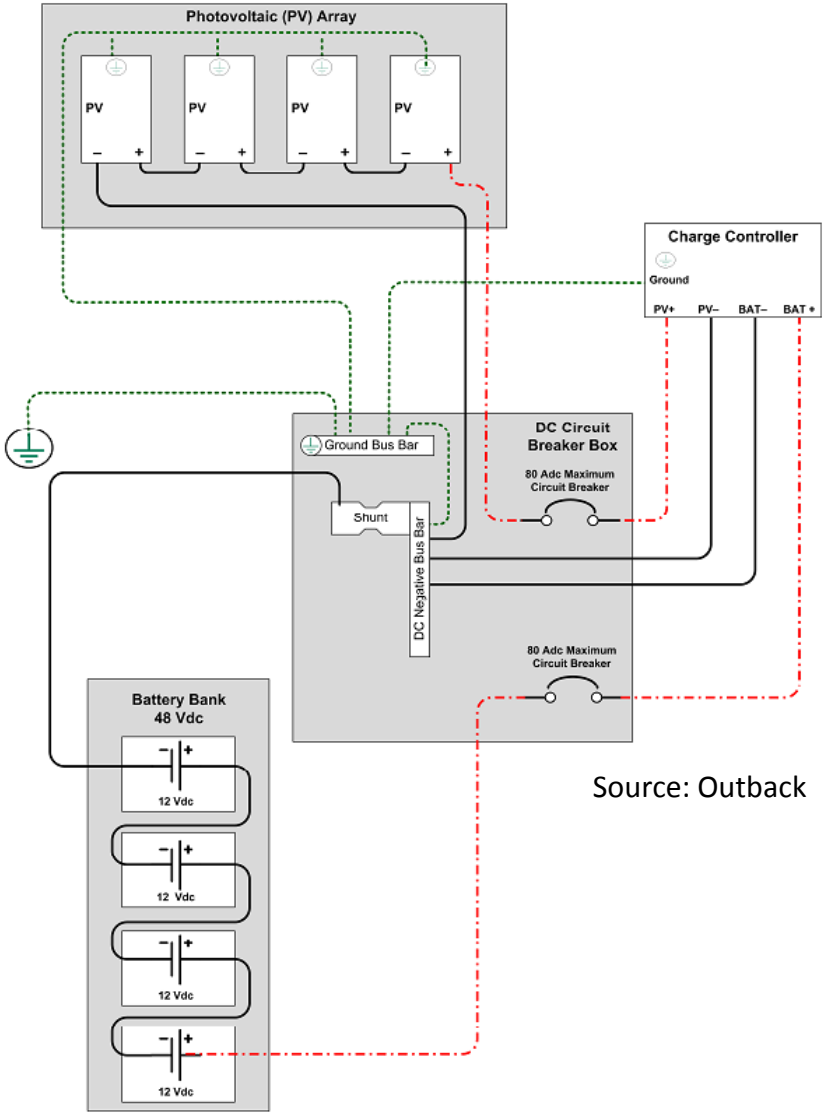
5.Keep the cover off until wiring is completed.

The conduit nipple assembly creates a sealed connection from the FLEXmax to the enclosure.



Source: Outback

Outback – Flexmax: Application



Source: Outback

Outback – Flexmax: Application

MPPT Bulk

This is a Maximum Power Point Tracking mode which harvests the maximum wattage available from the PV array. The controller is trying to regulate the battery voltage towards the Absorbing voltage set point. Normally the charge controller enters this mode at the beginning of the day or when a new charge cycle begins. The controller may also enter this stage if there is not enough PV energy to maintain a different stage, such as Absorbing.

MPPT Float

This is a Maximum Power Point Tracking mode which harvests the maximum wattage available from the PV array. The controller is trying to regulate the battery voltage towards the Float voltage set point. Normally, the charge controller enters this mode if it was in the Floating mode (see above) and there was not enough energy to maintain the battery voltage.

Outback – FX Series Inverter

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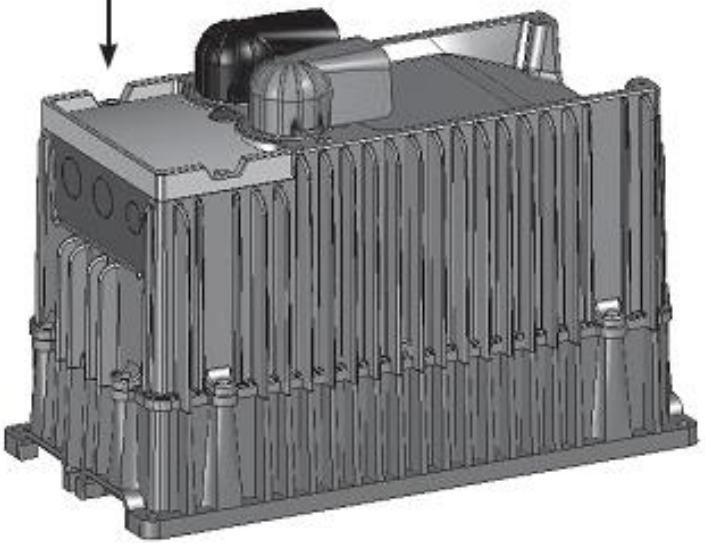
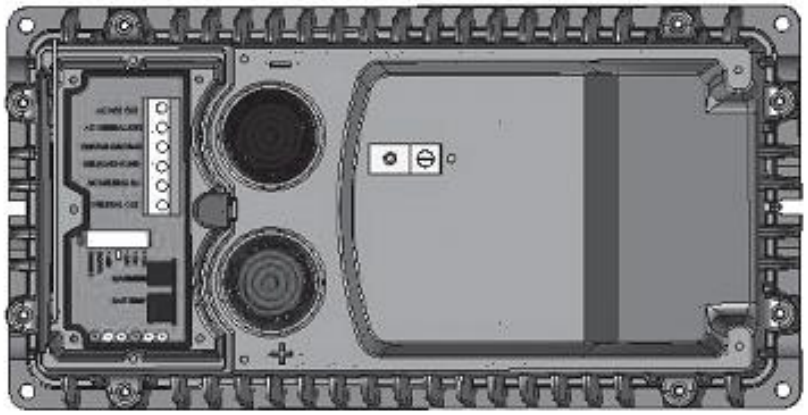
Lexan cover protects AC Wiring Compartment Board



AC Wiring Board



Source: Outback

Outback – FX Series Inverter

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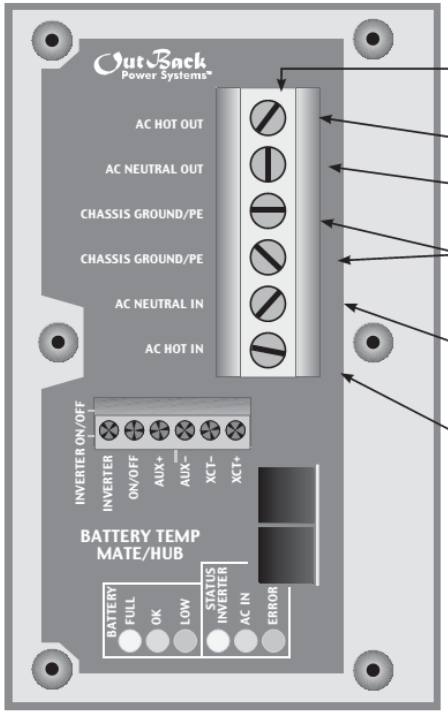
AC WIRING COMPARTMENT BOARD



AC Terminal Block--secures AC connections to the FX using set screws

AC HOT OUT supplies power to the loads.

AC NEUTRAL OUT acts as neutral leg for loads supplied by the FX.

CHASSIS GROUND connections are common and act as grounds for both the incoming and outgoing AC circuits.

AC NEUTRAL IN acts as the neutral leg for AC power supplied by either the grid or a generator to the FX.

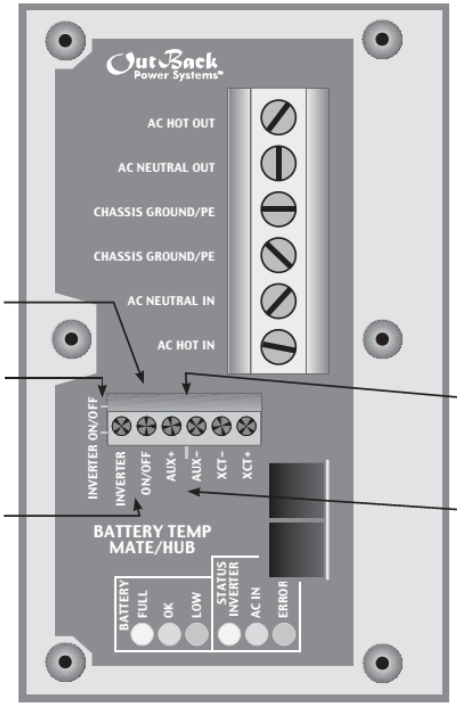
AC HOT IN connects incoming AC from the grid or a generator to the FX. This AC is used to run loads and recharge batteries.

M

NOTE: "CHASSIS GROUND" in the AC terminal block reads as "NEU/GROUND BOND" ON FX MOBILE SERIES (see page 21).

NOTE: 6 AWG (4.11 mm) is the largest wire size the AC Wiring Compartment Board can accommodate.

LOW VOLTAGE TERMINALS



Control Wiring Terminal Block

Jumper

INVERTER ON/OFF: allows for manual switch to control the FX (default operation is "ON"); controlled by the MATE when the installed jumper connecting these terminals is present.

NOTE: Keep Control Wiring Terminal Block screws tight and the block itself secured tightly to AC Board. Otherwise, the FX can malfunction. The Terminal Block can be unplugged for easier wire installation and removal/ reinstallation of the FX.

AUX OUTPUT (AUX+/AUX-): 12VDC at 0.7 amps (8.4 watts) maximum is available at these terminals; the AUX's default is to drive cooling fans or the Turbo Fan.

XCT+/XCT- are non-operational terminals (do not connect).

Source: Outback

Outback – FX Series Inverter

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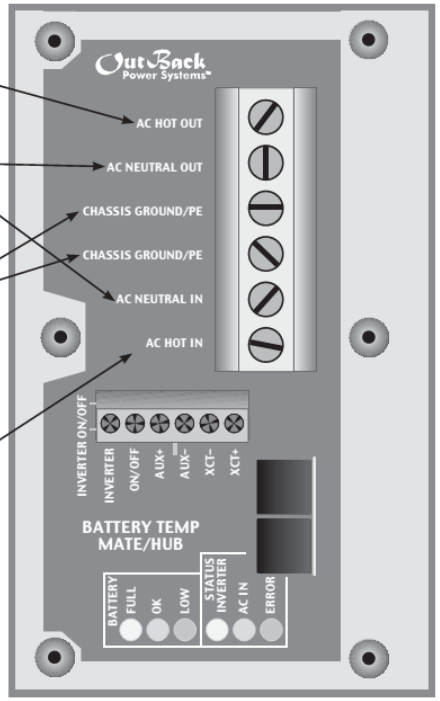
AC WIRING NOTES FOR THE NON-MOBILE FX

AC HOT OUT
- AC hot output conductor (black) wire gauge must be sized to the breakers and loads.

AC NEUTRAL OUT/AC NEUTRAL IN
- Both neutral terminals are common with each other within the FX.
- Only one neutral needs to connect at the terminal if a separate common neutral bus bar is installed.

CHASSIS GROUND
- Both CHASSIS GROUND terminals are common within the FX.
- The AC input and AC output ground wires can connect to these terminals or one can be connected if a common ground bus bar is installed.

AC HOT IN
- The AC hot input conductor (black) must be supplied through a 60 amp maximum AC branch rated circuit breaker.
- 6 AWG (.184" or 4.11 mm) wire is recommended for the FX's AC transfer relay.



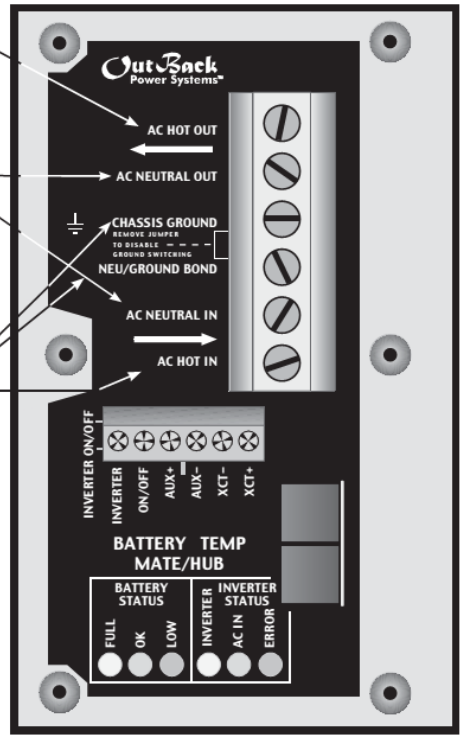
AC WIRING NOTES FOR THE MOBILE FX

AC HOT OUT
- Supplies the AC hot output conductors through a 30 amp maximum AC branch rated circuit breaker using 10 AWG (.102" or 2.59 mm) wire and connect to the AC

AC NEUTRAL OUT/AC NEUTRAL IN
- Connects the AC neutral input conductor to the AC NEUTRAL IN terminal.
- Connects the AC neutral output conductor to the AC NEUTRAL OUT terminal.
- These terminals are common in the Mobile FX only when an AC source is applied.
- The NEUTRAL IN and NEUTRAL OUT conductors should not be common (connected in any way) prior to connection with a Mobile FX

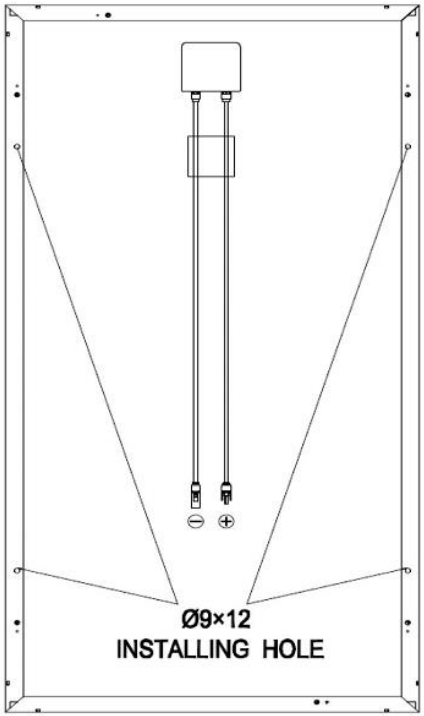
CHASSIS GROUND
- Connects both the AC input and AC output ground conductors to the CHASSIS GROUND and NEU/GROUND BOND terminals.
- If there is only one Mobile FX in the system, leave the copper bus (provided) installed between the CHASSIS GROUND and NEU/GROUND BOND terminals. If there is more than one Mobile FX in the system, remove the copper bus from every Slave FX.

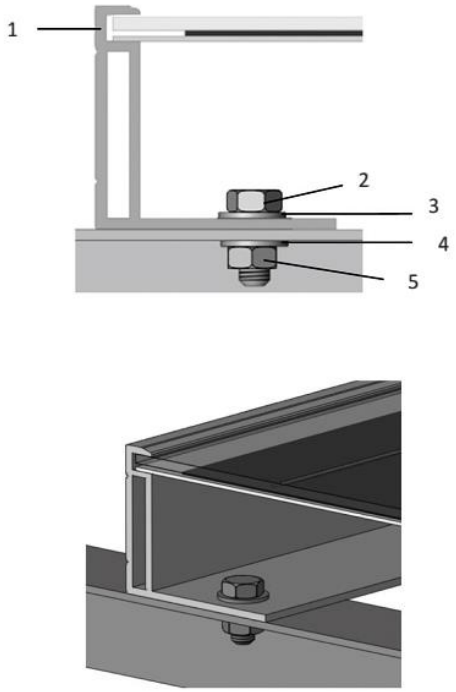
AC HOT IN
- The AC hot input conductor (black) must be supplied through a 30 amp maximum AC branch rated circuit breaker and connected to the AC HOT IN.
- 10 AWG (.102" or 2.59 mm) wire is required for the FX's AC transfer switch.



Source: Outback

PV Module installed with screw fitting methode





Source: Trina Solar

1. Aluminum frame
2. M8 stainless screw
3. Flat stainless washer
4. Spring stainless washer
5. HEX stainless nut

PV module installed with clamp fitting method

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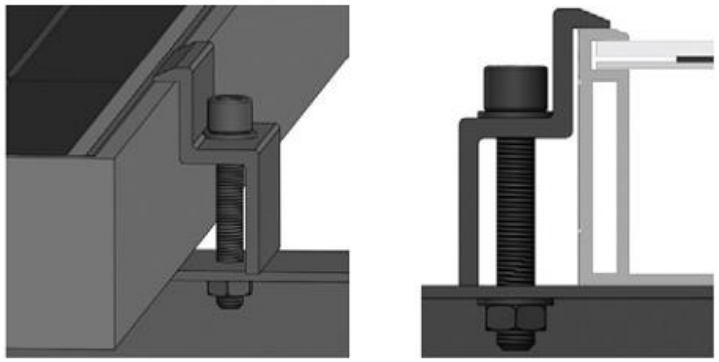
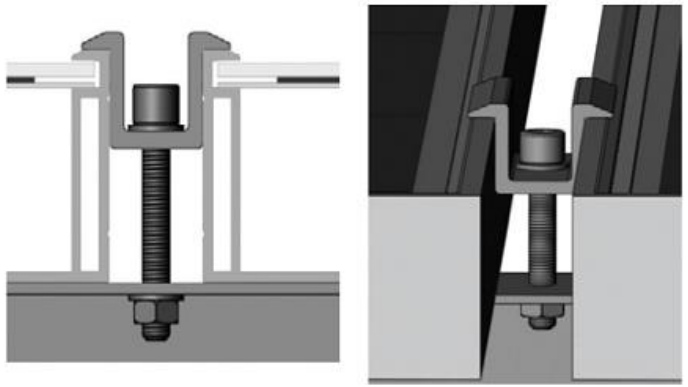
Clamp fixing

- Trina Solar have tested our modules with a number of clamps from diffrent manufacturers and recommend the use of clamps which have an EPDM or similar insulatig washer, fiing screw of at least 6mm. The clamp must overlap the module frame by at least 7mm but no more than 10 mm.
- Use at minimum 4 clamps to fi modules on the mountig rail.
- Module clamps should not come into contact with the front glass and must not deform the frame.
- Be sure to avoid shadowing effcts from the module clamps.
- The module frame is not to be modifid under any circumstances.
- When choosing this type of clamp-mountig method, use at least four clamps on each module, two clamps should be attched on each long side of the module (for portrait orientatin) and each short sides of the module (for landscape orientatin). Depending on local wind and snow loads, additinal clamps may be required to ensure modules can bear the load.
- Applied torque should be 8 Nm. Please fid detailed mountig informatin in the illustratin below:

Fringe modules installation



Middle modules installation



Source: Trina Solar

Wire loop design recommendation

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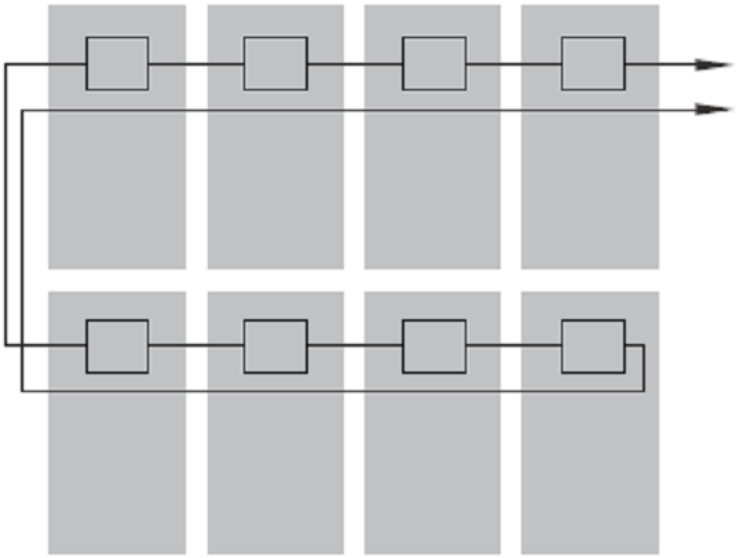
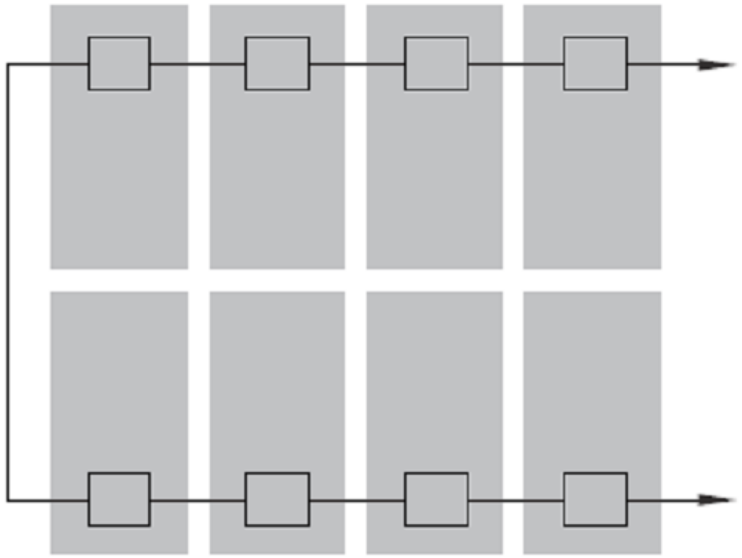
Ideal wiring loop



Greater risk of lightning induced voltage surge

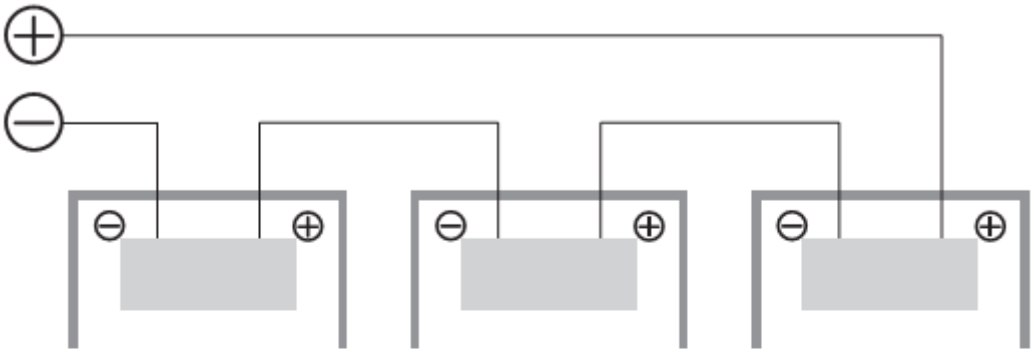


Source: Yingli Solar

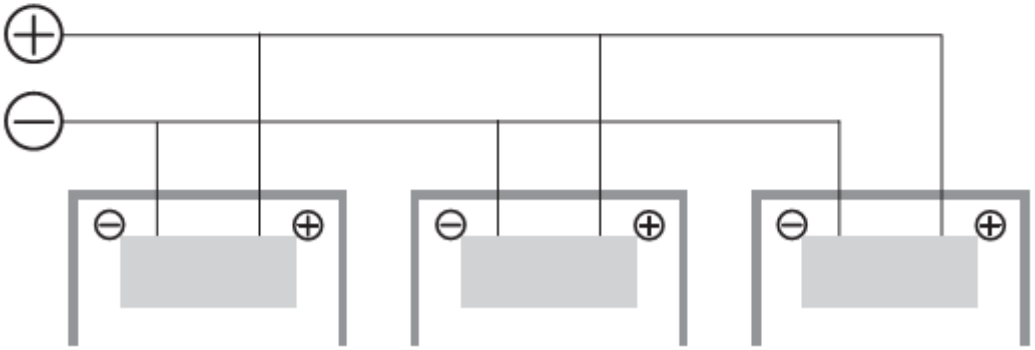
Series and parallel wiring

The maximum number of PV modules that can be connected in a series string must be calculated in accordance with applicable regulations in such a way that the specifid maximum system voltage of the PV module and all other electrical DC components will not be exceeded in open-circuit operation at the lowest temperature expected at the PV system location.

Series wiring (voltage additive)

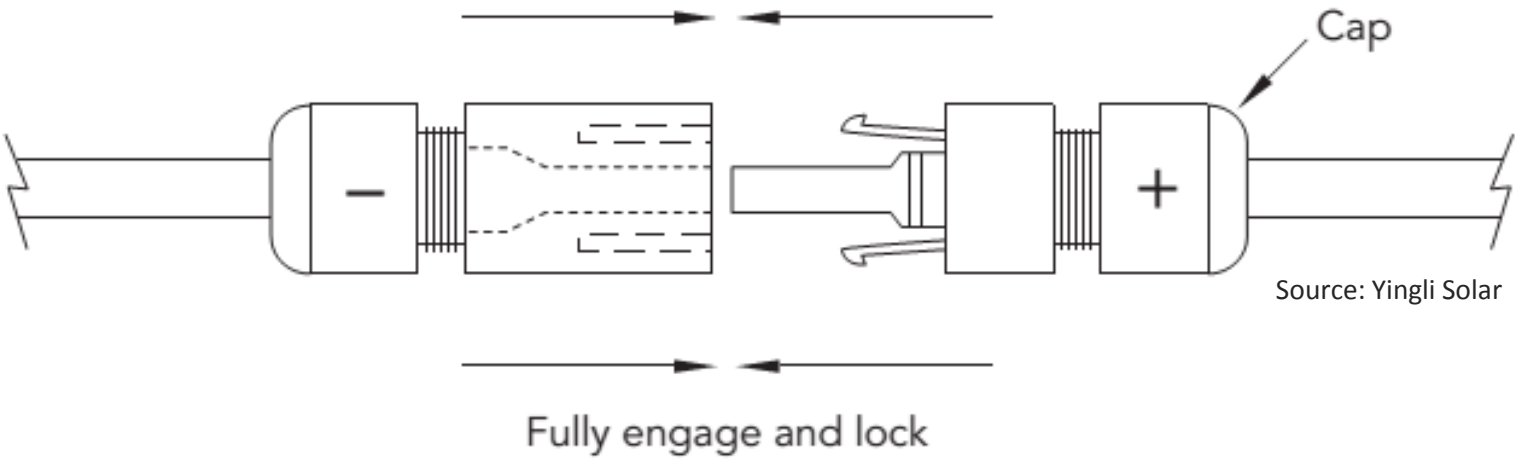


Parallel wiring (current additive)



Source: Yingli Solar

Connectors

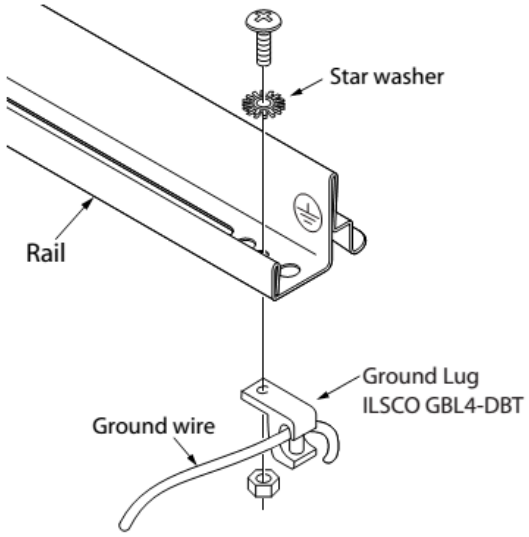


Source: Yingli Solar

Faulty connections can result in arcs and electrical shock. Check that all electrical connections are securely fastened. Make sure that all locking connectors are fully engaged and locked.

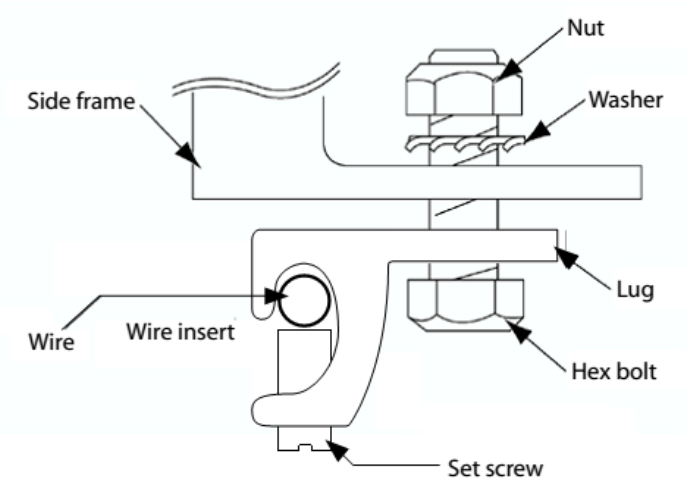
Grounding

RAIL GROUNDING



Use a # 10-32 x 1" stainlesssteel machine screw, lock washer and nut.

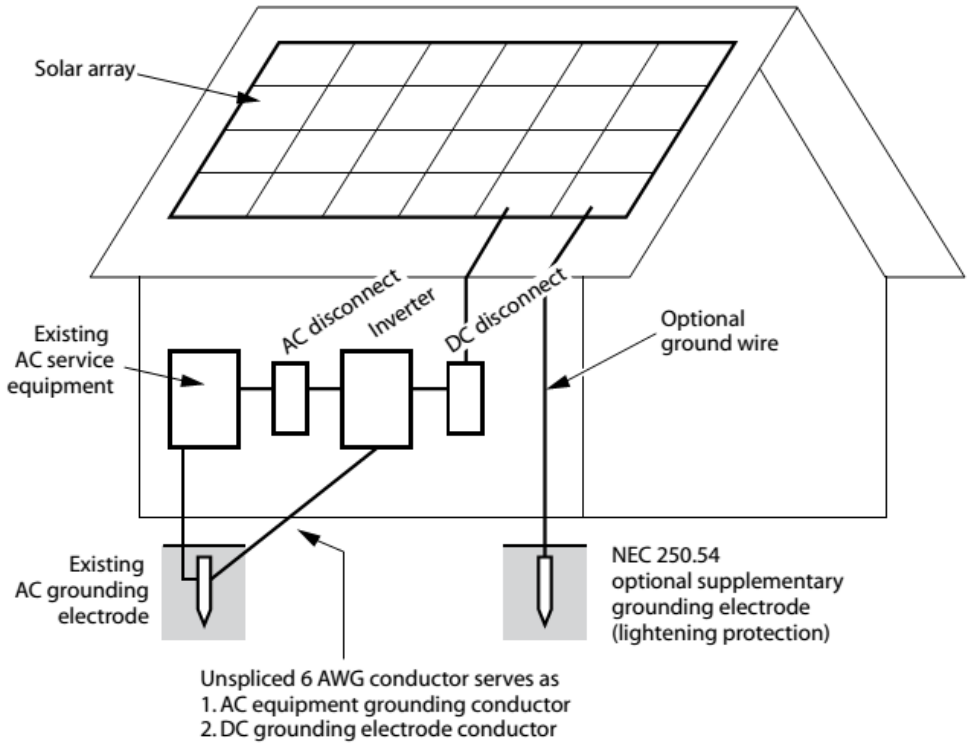
MODULE GROUNDING



http://www.npcpsolar.com/

The frame of the PV module, as well as any exposed non-current-carrying metal parts of fied equipment that are able to become energized by the PV system, must be connected to the equipment grounding conductor (EGC) in order to prevent electrical shock.

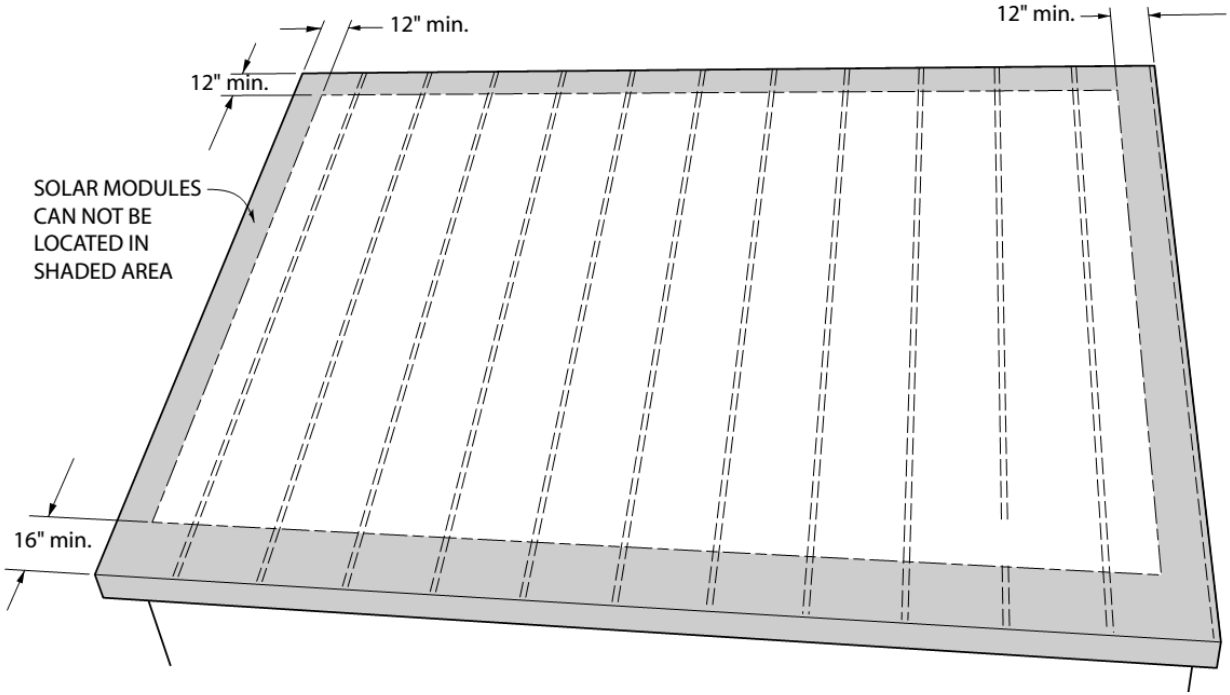
Grounding



Accomplishing a code compliant grounding system is critical to the safety of the system. Continuous grounding of all modules and mounting system components is required.

1. Install outdoor rated ground lugs or ring terminals with ground wire (per above drawings). Use the marked ground hole on
   either end of the rail.
2. Connect a minimum # 10 AWG solid conductor, copper, ground wire to the ground lug or ring terminal.
3. Land the end of the ground wire in the array
   junction box.
4. Run the ground wire to the DC disconnect
   and inverter.
5. Run the ground wire from the inverter to a ground rod.

Array Layout



http://www.npcpsolar.com/

The array must be installed at least 1 6" away from the eave of the roof and 1 2" from the sides of the roof. This border will enhance the wind load resistance of the system.

Measure the perimeter of the roof surface where the array will be installed.

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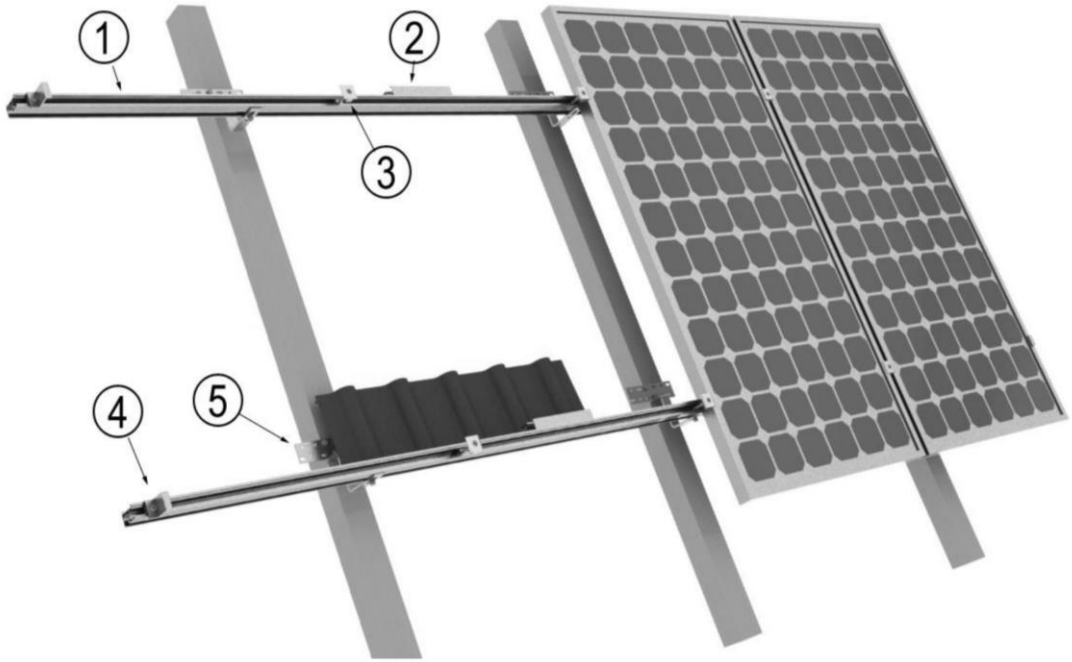
All components of the system are listed below. The version and quantities of the parts can vary, depending of

- Type of roof
- Number of modules
- Type of module
- Site specifics



① GS Rail	② GS Rail Splice
③ Inter Clamp	④ End Clamp
⑤ Roof hook	

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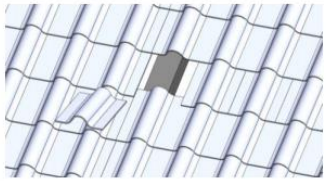
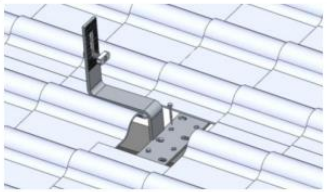
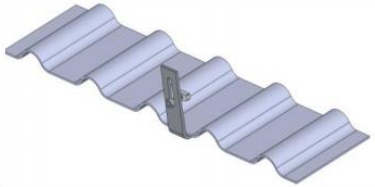
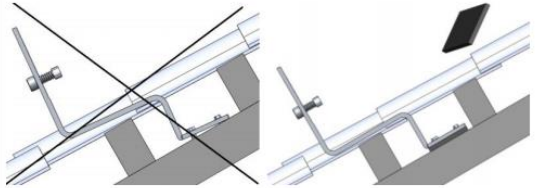
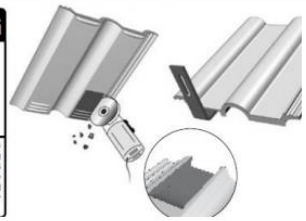
Install on Roman Tile Roof	
1. Remove the roof tiles at the marked positions or simply lift them up slightly.	
2. Input the roof hook to the wooden beam. Fix the roof hooks with 3x wood screws (M6x80).	
3. Cover the hooks by the removed tile	
4. The roof hook must not press against the roof tile. Place it flat. If necessary, shim the roof hook with wood.	 Wrong Correct
5. If necessary, use an angle grinder or hammer to cut a concavity in the tile that covers the roof hook at the point where the roof hook comes through. (Caution! Must not use fixed roof hook as a ladder, as this extreme point load could damage the tile below.	 

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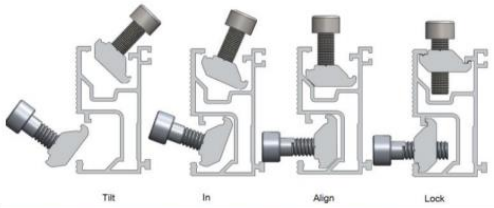
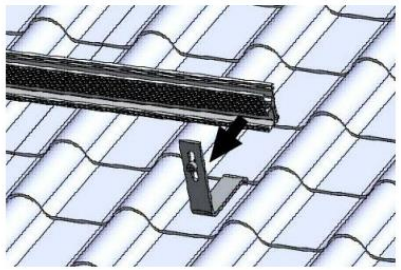
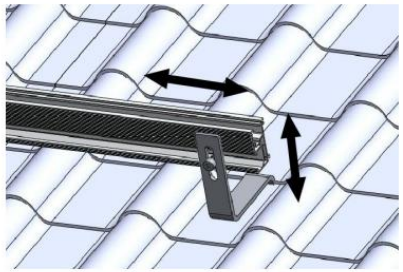
Install The GS Rail

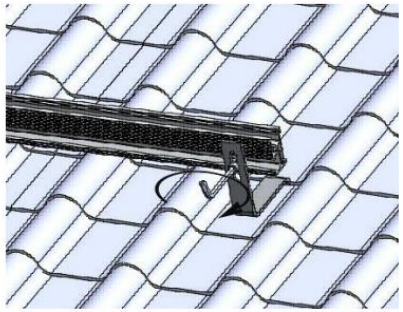
9. Tilt-in module quick mount.
   Four steps to quick mount the tilt-in module into GS rail channel.
   Move the assembly to
   It's desired final position, and
   fastens firmly in place by torque bolt to 10Nm.



10. Connect the roof hook with the GS rail.
    a. Insert the tilt-in module into the side channel of the GS rail as the step 9 shown.
    b. Adjust the GS rail to be level.
    c. Fasten the bolt.







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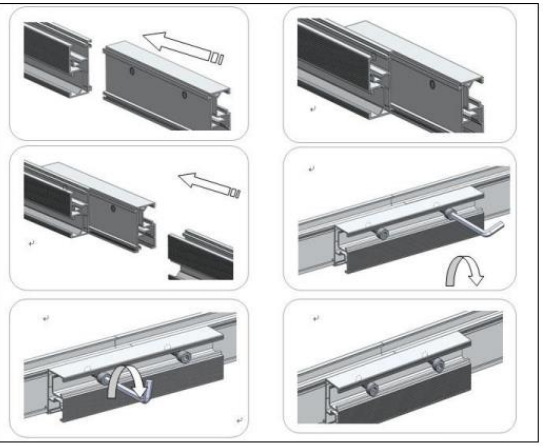
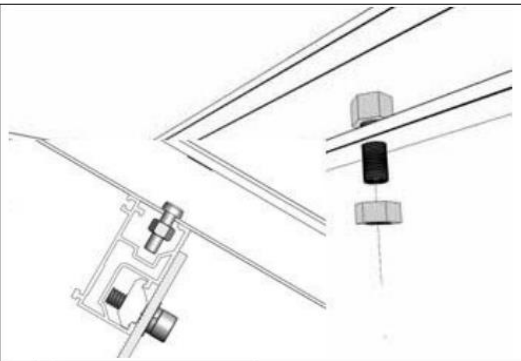
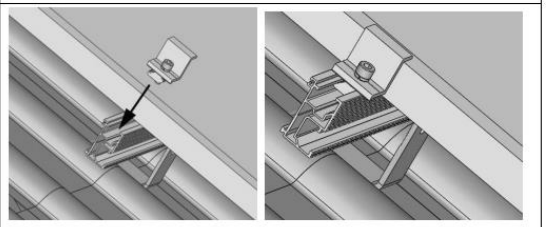
11. GS Rail connect Installation of the splice to connect multiple rails together. Slide the splice on the rear side of the pre-assembled rails. Fasten the first bolt firmly. Then slide the next rail into the splice. When comes together, fasten the other bolt. The connection is finished. An expansion gap at the rail joints is suggested. Leave a gap about a finger width.	

Install the module	
12. Installing anti-slip protection The anti-lip protection is only necessary on the lowermost row of modules. At first, fit two bolts M6*20 and nuts into the lower holes of each module. Then place the first module of the bottom row so that the anti-slip protection sits in the rail channel of the lowest row of rails	
13. Fixing the outer modules by End clamp. a. Put the end clamp kit into the top channel of the GS Rail as the step 9. b. Push the side of module to firmly against the end clamp and then fasten the bolt.	

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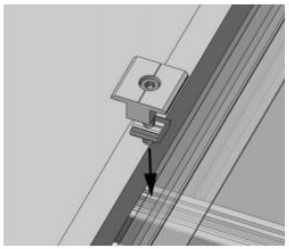
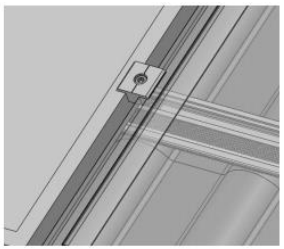
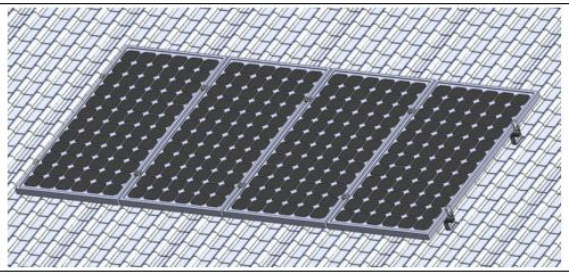
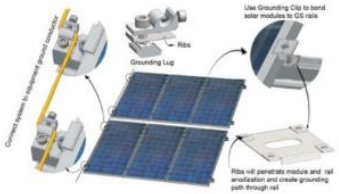
14. Fixing the inter modules by inter clamp. a. Put the inter clamp kit into the top channel of the GS Rail as the step 9. b. Push the Inter-module clamp firmly against the already fixed module. c. Push the next module against the other side of the module-inter clamp. d. Tighten the bolt	 
15. Installing the further rows of modules	

Cable tie and Grounding	
16. Tie cable with the rail a. Tie the cable with the rail using the zip tie b. Using Plastic cable clip to manage the cable.	 
17. Grounding Please see the *Grace solar Grounding System Installation Guide*	

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