Fronius System Configuration Tool – *Help!*

(*Siento, esto solo está en inglés*)

Introduction

The FSC Tool should be intuitive by itself. *You do not have to read this help file to use it. Consider this as a reference when you desire a more in-depth understanding*. In addition, hovering your pointer over the question mark images (?) provides a '*Tool Tip*.'

Click here to jump to a definition list for abbreviations and acronyms used in the FSC Tool.

Recent Updates

- Jan 2021: Message added notifying users this tool will no longer be updated. See the NOTE in the next section for the official new tool.

Intended Use and Disclaimer

The Fronius System Configuration Tool ("FSC Tool") for North America can assist you in PV system design, but as building codes and system conditions vary from site to site, it is not possible for software to completely account for all of these. For example, if you believe irradiance will exceed 1,000 W/m^2 (Watts / square meter), you must account for the resulting increase in current above the module's STC values. As this Tool is intended for North America use, it only contains Fronius inverter models for North American grids and tested to UL standards. Finally, the FSC Tool is a string-sizing and inverter configuration tool, and thus it doesn't calculate expected energy production or any other financial, engineering, or performance concerns (ROI, wire sizing, optimal tilt, etc). *By using this tool, you agree to verify all calculations*.

NOTE: Fronius International GmbH provides an on-line tool accessible via the Solar.Web site or directly at Solar.Configurator 4.0 ("SC4"). These links are also found at the bottom of the FSC Tool page. The FSC Tool will be made available to customers until demand for it ceases to be significant. The international online tool (SC4) is fully vetted for North American use. For best features on the SC4 platform, log into Solar.web (or create an account to do such).

Versions

The top of the screen displays a release month-year in parenthesis (e.g., Jun-2020) and the browser tab shows a version number (e.g., v9.33). There might be more than one release in a given month which results in the month-year indicator not changing but the version number increasing.

The Single and Dual MPPT Configuration Reports include the FSC Tool release number at the bottom. That way you can always see what version of the Tool was used to generate that report.

If the online version is displaying a version more than 1 month old, try doing a browser refresh (Ctrl-F5 on Windows; Apple + R or Cmd + R on a iOS; F5 on Linux) so your browser obtains the latest files.

Recommended Browsers

This tool has been tested in Google Chrome, Mozilla FireFox, and MS Edge. All work but traditionally Chrome was best while MS Edge was the slowest. Now Edge renders like Chrome because they both use the Chromium open source project browser. Avoid using MS Explorer due to potential alignment issues in string matrices (and Microsoft's intent to no longer support it). The site url = *www3.fronius.com/froniusdownload/tool.html*

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Getting Started

Language Selection

The Tool loads in English but offers an En Español button. Upon selection, the screen reloads in Spanish and provides an In English button.

The English and Spanish versions use the same electrical calculations. However, there will be some differences in configuration report layout. Many of the pop-up messages are in English only.

While this help file is only in English, many *Tool Tips* are available in the Spanish version. For a completely Spanish version of a Fronius string-sizing tool, see the Solar Configurator v4.

PV System Design Parameters

While some of these input parameters are informational only, most have some effect on string-sizing, inverter configuration, and code consideration. Make sure you review all inputs before making your final string-sizing selection.

Required vs Optional Inputs

Required input fields will be indicated by a very light red background color. Selecting a value is required for proper calculation of PV string-sizing options. Optional inputs can help the FSC Tool guide you in subsequent selections and will affect the information on the Configuration report.

Overall Project Information

Project Name

Enter the customer, site, or project name or id. Here are some examples:

- Jack Smith House
- Terri Jones Barn
- Oak High School Inv#4
- Ice cream museum roof B

The Project Name will appear atop the Print Version which is available after you select the following System Input Parameters and choose your stringing configuration.

Country

You can select a North American country or territory - United States, US Territories, Canada, or Mexico – or a Caribbean territory nation or country. Except for Mexico, if you choose an option here, an optional sub-selection of state/province/territory appears. Your choice is shown on the Configuration Report. The only other benefit is that selecting 'United States' provides blue italic text indicating the selected inverter's California Rule 21 compliancy and offers up the Applicable Electric Code selection list.

Applicable Electric Code

This field only appears if the Country selection is United States. If visible, select the electric code that applies for this project (i.e., the NEC edition). Note that there are still references to the NEC in the Tool even if United States is not selected because the NEC is often applied outside the USA (e.g., *El NEC®* de México).

AC Service

While this section is optional, it is beneficial to select values here as it results in filtering the inverter list to those inverters that can interconnect to the AC service defined by these selections. In addition, the AC service you define will be shown on the Configuration Reports.

UL Inverters for North America

The Fronius inverters sold in the NAFTA market (CAN, USA, MEX) are different from those sold in the rest of the world (RoW). North America doesn't use the same method of *system* grounding as most of the RoW and has different standards (e.g., UL 1741 instead of IEC 62109). Fronius provides UL-listed inverters designed for North American electrical distribution grids that expect such system grounding (Don't confuse with ungrounded (or "floating" systems on the DC side). So don't install RoW Fronius inverters in North America without checking with your closest Fronius subsidiary (you cannot get such inverters from Fronius USA or Fronius Canada).

Phase Count

Indicate the number of phases of the project site's AC electrical service: 1-phase and 3-phase. Making a selection here will cause the next selection input to appear (Voltage).

Single Phase

This service is predominantly 240V split-phase: single phase secondary service transformed to two opposing phases by center tapping the secondary winding to derive a neutral. You *can't use a 3-phase inverter with a single-phase grid service*.

Three Phase

Typically, you will use a 3-phase inverter with 3-phase service. However, it is technically possible to design with 3 single-phase inverters to connect to a 3-phase service. This is generally not recommended since Fronius offers 3-phase inverters of various grid types (see Transformer Secondary below).

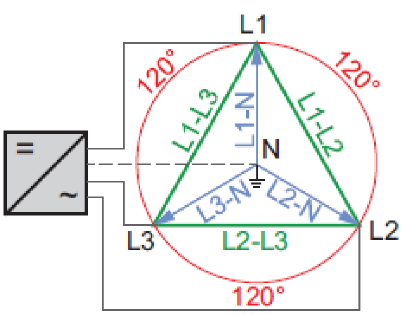
Voltage

This selection input only appears if a Phase Count is selected. Regardless of the Phase Count selected, this list is always the same (208, 220, 240, 480 V). These are line-to-line (L-L) voltages, not line-to-neutral (L-N) voltages.

Transformer Secondary

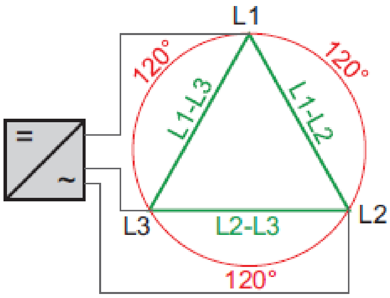
In North America, three-phase service consists of 3 hot conductors with each having voltage and current being 120° out-of-phase with the other two hot conductors' voltages and current. This is accomplished with either a wye or delta winding setup.

Wye (star)

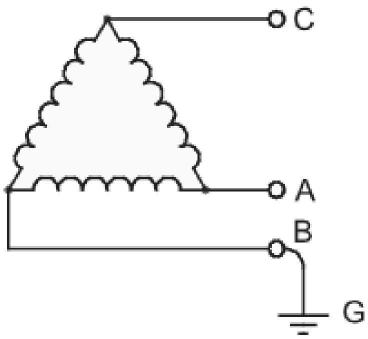


The secondary windings are represented by the blue lines. Note how the blue lines form a 'Y' or star shape: ergo the descriptor "wye". Each power line (or leg, L1 – L3) has a winding with the center neutral.

Delta

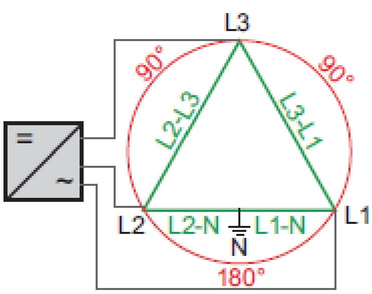


there is no neutral conductor; secondary windings are between service lines L1, L2, & L3:



one of the conductors is grounded (required for a grounded system).

High-leg Delta



L3 is the high-leg (aka stinger) relative to neutral.

In the case of a High-Leg Delta service, the Symo 10.0-3 and 12.0-3 208-240 are the preferred inverters, but a single-phase inverter could be used on just the two phases that have a derived neutral. HOWEVER, one must *be careful not to imbalance the utility service by over-feeding only 2 of the 3 phases*.

Open Delta Warning!

An Open Delta has 3 lines and 3 phases but only 2 windings. One way to recognize such a service is if there are only be two transformers instead of three. *While Fronius 3-phase inverters would theoretically work with such a service, they have not been tested and are not warrantied for such use*.

Ambient Temperatures for System Design

The **Ambient Temperatures** selection lists show Celsius (and Fahrenheit equivalent) values in one degree increments. You need to know the *Expected Coldest* and *Average Hottest* ambient ‘dry-bulb’ temperatures for your PV site location. PV module voltage has an inverse, linear relationship to temperature, and thus temperature extremes must be considered in determining potential string voltages.

Terminology

Expected Coldest

It is acceptable, but conservative, to use the minimum recorded temperature, since this would yield the highest possible V_{OC} at the site. However, it is also appropriate to consider the *expected* minimum temperature if it's highly unlikely to obtain the minimum recorded temperature in the system lifetime during daylight. This will result in a lower PV string V_{OC}, which may allow for a longer string length. The ASHRAE database provides an 'Expected Minimum' temperature (*Extreme Annual Mean Minimum Design Dry Bulb Temperature*) which is less conservative than the Record Coldest. Regardless which you select, please bear in mind the maximum allowable V_{OC} for your selected inverter (i.e., 600 V or 1000 V). It is the system designer's responsibility to make sure this voltage limit is never exceeded. *Any damage resulting from the inverter being subjected to voltages in excess of these voltages will void the Fronius warranty*.

Average Hottest

Unless PV system operation is critical regardless of how hot it gets outside, it is recommended to use the *average annual* hottest ambient temperature for the given site and not the record hottest temperature (in the next section there are references to average hot temperatures for given temperature databases). It is important to make sure the string operating voltage (V_{MP}) is above the minimum operating voltage of your selected inverter during typically-hot conditions. Remember to allow for voltage degradation as the modules age (generally 0.4 to 0.7% per year); voltage degradation is NOT accounted for in this Tool.

Data Source

You may indicate the *data source* of the selected temperatures by selecting the database from a list and then entering a description of the source site (e.g., "ASHRAE" database and "Los Angeles AP" site). This value pair will show up on the Configuration Report.

Historical Temperature Databases

An industry standard source of such historical temperature data is an ASHRAE database. NEC Article 690.7(A) provides an Informational Note referring to such data as an example of Expected Coldest temperature. Since the NEC doesn't limit use to the ASHRAE data, the FSC Tool provides links to two ASHRAE sources plus Weather.com. All are mentioned below but described in detail in Appendix B:

1. Solar ABC's Solar Reference Map provides a graphical mapping interface to an ASHRAE database (2009) of extreme temperature statistics for all 50 US states (1,042 sites).
2. Weather.com via the 'Monthly' view provides *Average* and *Record* temperatures for each month.
3. ASHRAE-METEO Info provides a more sophisticated graphical mapping of three databases (2009, 2013, 2017) for international weather sites.

These links and descriptions are also provided in the FSC Tool. Just click on the information icon in the Tool (to the right of the section heading as illustrated below in yellow highlight):

Inverter Model

Select the Fronius Inverter that is most appropriate based on electrical service type selected and expected PV system size. By default, this field is empty but an inverter must be selected. Options for selecting system voltage and having MPPT-2 activated will appear if appropriate for the inverter model selected. To see detailed inverter information, click the Information icon (i) after selecting an inverter.

Current Production SnapINverter models for North America

Line	Inverter	Max AC output (W)	AC Voltage	DC Input Voltage (open-circuit)	DC Max Current Usable / Warranted
Primo	3.8-1	3,800	1 Φ 240 V / 208 V	80-600 V (1,000 V capable)	MPPT-1: 18 A / 27 A MPPT-2: 18 A / 27 A Inverter: 36 A / 45 A
	5.0-1	5,000			
	6.0-1	6,000			
	7.6-1	7,600			
	8.2-1	8,200 W @240 V 7,900 W @208 V			
	10.0-1	9,995			MPPT-1: 33 A / 49.5 A MPPT-2: 18 A / 27 A Inverter: 51 A / 63.8 A
	11.4-1	11,400			
	12.5-1	12,500			
	15.0-1	15,000 W @240 V 13,750 W @208 V			
Symo Advanced	10.0-3 208-240	9,995	3 Φ (3 phase)	200-600 V	MPPT-1: 25 A / 37.5 A MPPT-2: 16.5 A / 24.8 A Inverter: 41.5 A / 62.3 A
	12.0-3 208-240	11,995			
	15.0-3 480	14,995	3 Φ 480 V only	200-1,000 V	MPPT-1: 33 A / 41.3 A MPPT-2: 25 A / 37.5 A Inverter: 51 A / 67.5-76.5 A
	17.5-3 480	17,495			
	20.0-3 480	19,995			
	22.7-3 480	22,727			
	24.0-3 480	23,995			
Symo	15.0-3 208	15,000	3 Φ 208 V only	325-1,000 V	50 A / 75 A

For older inverters, see Appendix A.

- All the *Primo* and *Symo Advanced* SnapINinverters have Dual MPPTs and a maximum warrantied DC/AC ratio = 1.5 (150%).
- The *Symo 15.0-3 208 V* has only 1 MPPT and a maximum warrantied DC/AC ratio = 1.4 (140%).
- Due to their built-in fusing option ("Eco fusing"), the Large Primos (10-15 kW), the Symo 15.0 208 V, and the Symo Advanced 20-24 kW 480 V are limited to 15 A per DC terminal for MPPTs with more than 2 terminals; as such copper distribution bus bars (included with product) or 'jumper' wires (installer created) may be required.

NOTE: The older Symos and newer Symo Advanced models of the same AC power capacity and nominal voltage have the same electrical characteristics such that string-sizing for one will work for the other.

Legacy inverters

Older Fronius models are included since it's possible they might be re-used in a different system or have their modules changed or another array added. Such models are indicated with an asterisk (*) at the end of their displayed name.

PV System Maximum Voltage option

If the selected inverter is rated up to 1,000 Volts open-circuit (NEC 690.7(A)), the ability to select the intended Maximum PV System Voltage is displayed with the following radio button options:

- Max PV System Voltage (Voc): ◉ 600 V ○ 1,000 V

Otherwise, an *italic* warning will display showing the 600 Voc limit.

NOTE: the inverter's nameplate sticker shows the maximum Voc rating; however, the *operating* voltage limit will be less. The SnapINverter Primos & Symos that can handle 1,000 Voc generally should not be exposed to operating voltage above 800 V. Those Symos that can handle only 600 Voc should not be exposed to operating voltage above 480 V.

Dual MPPT Configuration

- MPPT2 Setting: ◉ 'ON' ? ○ 'OFF' ?

This configuration option is displayed if the selected inverter features dual MPPTs *and* MPPT2 can be disabled; otherwise, the option is hidden. The user selects the MPPT-2 setting with a radio button as follows:

- **MPPT2 'ON'**: *MPPT-2 is enabled;* its terminals are independent of MPPT#1 terminals. To prevent erratic and inefficient performance, *Do Not* enable MPPT#2 if it shares the same PV circuit as MPPT#1. Such circuit sharing occurs when distributing a PV circuit over both MPPTs via a distribution block or jumper wire. Doing so will cause the MPPT's to compete for optimization control of the single PV circuit.
- **MPPT2 'OFF'**: *MPPT#2 is disabled;* if there are no wires on its terminals or those wires share the same combined circuit as MPPT#1, either via a distribution block to all DC terminals or a 'jumper' wire connecting the two MPPTs.

AC Connection Mode

All Fronius inverters are intended for 'on-grid' use. By default, they perform testing of their AC connection for proper AC waveform (i.e., stays within expected voltage and frequency of selected country setup code selected) and grid impedance seems low as expected with a true utility grid / EPS. Fronius inverters prior to the SnapINverter Primos and Symos perform a grid connection test (pulse impedance test for anti-islanding) that will likely fail in a microgrid setup (e.g., AC coupling with direct connection of Fronius inverter to battery inverter), resulting in inverter shutdown and restart.

The Primo and Symo SnapINverters have a more tolerant anti-islanding test method; the inverter should stay connected and inverting while the microgrid's AC waveform stays inside expected norms of frequency and voltage. The SnapINverter should shutdown when microgrid waveform (typically voltage) has excursions outside AC norms. If this is undesireable, the Primo and Symo lines have a 'microgrid' mode option that disables the anti-islanding testing required for a 'utility interactive' connection.

- **'Utility Interactive'** mode: this is the default setting for Primos and Symos.
- **'Microgrid'** mode: this setting must be enabled and usually done at commissioning time in one of two ways:
  - Select an "MG#" setup code (see Installation manual for your inverter model)
  - Select a regular setup code and then turn off Anti-islanding mode via the 'PROFI' menu (call Tech Support at 877 FRONIUS if you are not familiar with accessing this menu).

California Rule 21 Compliancy

An *italic* message will display if the selected Country is United States AND the selected inverter has a level of California Rule 21 compliancy regarding 'smart inverter' features.

High Elevation Warning

Elevation has an impact on inverter cooling and electrical limits. An *italic* warning shows the selected model's maximum warrantied elevation. If your installation site is above 2,000 meters (6,500 feet) and you have selected a 480V model of Symo or Symo Advanced, please hover your pointer over the information icon to see the following Voc derating requirements:

All Symo & Symo Advanced 480 Vac SnapINverters have an open-circuit voltage input limit (Voc) that decreases with elevation above 2000 m (6,560 ft).

@ 2001 - 2500 m (6,562 - 8,202 ft) = 950 Vdc
@ 2501 - 3000 m (8,203 - 9,842 ft) = 900 Vdc
@ 3001 - 3400 m (9,843 - 11,154 ft) = 850 Vdc

The 208/240 Vac Symo & Symo Advanced SnapInverters do NOT have this voltage derating limitation.

PV Modules

While PV *modules* are technically only one type of PV collector (e.g., there are also tiles, shingles, etc), the term PV module here refers to all types. That said, the large majority of these *modules* are rectangular, framed, crystalline silicon (mono and poly) collectors.

>99% of all PV module data comes from Manufacturer data sheets or website (<1% from the CEC list or other databases). The Manufacturer STC Ratings table shows the source of the data (i.e., "Datasheet Version").

PV module characteristics can change slightly for the same model overtime; such intra-model revisions are generally not maintained in this Tool (though the PV module's datasheet version information is shown, if collected).

Mounting Method selection & derived PV Module Temperatures

It's important to indicate how the PV modules are affixed to an installation surface. This selection is not just informational but affects the module temperature calculation.

Average s*olar cell* temperature estimation method differs between coldest and hottest ambient temperatures:

The coldest module temperature = coldest *ambient* temperature. This coldest temperature in conjunction with the module's temperature coefficient for open-circuit voltage (Beta V_{OC}) determines the highest V_{OC}, per NEC [690.7(A)]

The hottest *ambient* temperature selection plus an additional *temperature offset* (based on Mounting Method and PV module NOCT rating) determines the estimated mean *solar cell* temperature at *average hottest expected ambient temperature*. This solar cell *temperature offset* mostly depends on the *average* height the bottom of the module is above the installation surface. The offset is determined by the Mounting Method selected. There are ten options to select from, each having an associated temperature offset:

1. Surface-mounted (BIPV): 0-1" 36°C (e.g., solar shingles)
2. Flush-mount racking: 2-3" 33°C (rack or *rackless* mounting above decking)
3. Flush-mount racking: 4-6" 31°C (rack or *rackless* mounting above decking)
4. Tilt-up racking: 6-8" 30°C (tilt-up rooftop mounting above decking)
5. Tilt-up racking: >8" 29°C (tilt-up rooftop mounting above decking)
6. Agrivoltaics fixed ground mount 28°C (ground mount just above vegetation)
7. Floating PV Array 27°C (PV arrays floating on body of water)
8. Single-axis tracker 26°C (e.g., East-West tracker)
9. Fixed ground-mount 25.5°C (no tracking; e.g., carport of field array)
10. Dual-axis tracker 25°C (East-West and North-South tracking)
11. Carport Shade or Trellis 24.5°C (Assumes fixed Array structure; not single pole)
12. Fixed Pole mount 24°C (single pole per PV Array)

These temperature offset estimates consider the ambient temperature next to the PV modules based on the airflow around the module and assume a POA (point-of-array) irradiation of 900 W/m^2. When modules are not flush-mounted to a solid installation surface (e.g., roof, ground, or wall), more air is able to flow under the modules to keep them cooler than in a flush-mount installation.

If you expect more or less module incident irradiation (POA irradiation), increase or decrease your *Average Hottest* temperature selection by one degree for every 50 W/m^2 delta from 900 W/m^2. See Air Gap in Appendix C for more information on the temperature offset for roof-mounted racking.

In addition to the temperature offset above, the Tool considers the PV module average NOCT value; specifically, its variance from the typical 45°C value. If the Tool lacks a NOCT value for the selected module, it assumes the common 45°C value.

Manufacturer & Model

Select the PV module Manufacturer. Then select the PV Module Model for this manufacturer, which is ordered in descending power rating (Watts); that is, higher power modules first.

Module List Power Filter

Since some Manufacturers have many models of PV Modules (new & old), the Model list can get long. To reduce the length of the Model list, enter a numeric value in the input field for Power Filter to limit the list to modules around that power level (*technically, the power rating is computed as Imp * Vmp instead of using the nominal rating provided by manufacturer*). The filter will remain in-place until one of the following:

- you remove it
- there are no modules around that power level for the selected Manufacturer
- you reload/refresh the FSC Tool browser page

Include Older Modules Checkbox

At least two-thirds of the PV modules in the FSC Tool database are no longer available in the market. Therefore it serves no benefit to include them if you are planning a new system. However, if you are retrofitting a system or were able to obtain older PV modules, select this checkbox to include them in the Model selection list.

STC Ratings Table

The nameplate specifications for the selected module are shown in the PV Module: Manufacturer Ratings table. In nearly all cases, electrical specifications are taken from manufacturers' datasheets. The *Beta* Temperature Coefficient (βVoc) and the selected Extreme Ambient Temperatures (see next section) are used *to calculate* the actual max V_{OC} and min V_{MP} which determines string-sizing limits. If the selected module is *bifacial*, this is indicated in a message and an input field is provided (see next section).

Bifacial Modules

If you select a bifacial PV Module, a message box is displayed (first time only) explaining a new input field that appears. Your input value into this new field will determine the power boost from rear side irradiation. This input appears in an expanded version of the Manufacturer STC Ratings table. Depending on how the PV module datasheet characterized the power contribution from the module rear side, the details table changes in one of two ways:

- *Normal* Percentage Gain: the percentage increase in module power from light incident on both sides over just reaching the front side. *Nearly all PV modules use this method.*
- *Normal* Incident Albedo: Albedo is expected percentage of light reflected off installation surface. The albedo that is incident upon the rear of module is the Incident Albedo. The value entered here is that incident Albedo *when front side is getting direct irradiation* (sunlight is perpendicular to module ('normal' radiation), not askew). When a PV module datasheet provides the STC values for voltage and current on the rear side of the module, this method is invoked in the FSC Tool (i.e., treated as needing an Albedo input. That Albedo ('reflectivity') is based on installation surface (e.g., roofing material) and surrounding structures, landscape, and weather conditions (wet surfaces or snow).

In either case, the table provides an input for a percentage value that determines maximum increased power expected. The term "*Normal*" refers to this rear side gain when the sunshine's is perpendicular to the PV module (thus receiving "normal" or direct irradiation). Enter a whole number but without the percent sign. The increase in overall power is due to increased current (due to increased irradiance) wired in parallel to the front side current.

Sample Modules

The FSC Tool has a pretend manufacturer ("123 Solar") for which there are at least 8 realistic PV modules of 4 types: Commercial, Residential, BIPV, and Bifacial. Use these for practice with the Tool.

Configuration Matrices

If any of the System Parameters are changed, the configuration matrix (matrices) will also change as needed. If the selected inverter features Dual MPPTs, two matrices will appear; otherwise only one matrix appears. You can revert the display back to one Matrix by selecting the "OFF" option for the MPPT2 Setting. Turning MPPT2 'OFF' would apply in the following scenarios:

1. If you are not landing any wires on the MPPT2 terminals
2. If the wires landing on MPPT2 *are from the same PV output circuit as wires landing on MPPT1* (e.g. when combined strings on the roof are then distributed among DC terminals for both MPPTs of the inverter)

*In either above 2 scenarios, remember to turn the MPPT2 Setting to "**OFF**" during last step of inverter commissioning!*

Design Parameters

Minimum and maximum string lengths are based on module voltage characteristics, inverter startup operating voltage, and maximum Voc which is the lesser of system voltage design or maximum input Voc of inverter. Below describes how these values determine string length. See Appendix D for actual calculation details.

Shortest String Length

The lowest number of modules per string is that which still provides a string V_{MP} greater than the inverter's startup voltage for the given *Average Hottest* temperature range selected. The V_{MP} is calculated using an *estimate*[1] of the module's temperature coefficient for operating voltage (Alpha V_{MP}) since such a value is rarely provided on the PV module datasheets.

Longest String Length

The Tool limits the number of modules per string by the selected inverter's input limits for voltage and power plus the PV module voltage during coldest ambient temperature. In reality, the PV module's series DC voltage limit also must be considered (e.g., a PV designer must make sure not to use older 600 V limited modules in a 1,000 V design).

Voltage Limits

There are two inverter voltage upper limits: *open-circuit* and *operating* voltages (Voc and Vmp, respectively). A PV module string cannot exceed either limit at the *Expected Coldest* ambient temperature selected. See Appendix D for calculation of temperature effect on string voltage.

The Voc maximum is the lesser of (1) the intended system voltage per the PV system designer (2) or the maximum open-circuit voltage allowed for a given inverter model. For example, a Primo inverter has a maximum Voc input of 1,000 V; however, the FSC Tool allows you to set a lower design limit ('System Voltage') to 600 V. See PV System Maximum Voltage Option.

The Vmp limit (aka Maximum MPP voltage) is generally less than the Voc but varies by inverter generation:

[1] Since PV module datasheets exclude the Vmp temperature coefficient, it must be estimated. This is usually done by substituting the Pmp temperature coefficient; however, earlier editions of the FSC Tool just used the Voc temperature coefficient ('Beta Voc') for estimation, and thus the PV module's Pmp temperature coefficient was not put in the FSC Tool's module database. Now the Vmp temperature coefficient is approximated using the Beta Voc as follows: Beta Voc * 1.3. While not as accurate as Pmp temperature coefficient, it is still better than using just the Beta Voc.

- SnapINverters: 80% of the Voc limit
- IG Plus & CL Series: 83%
- IG Series: 100%

Click on the inverter information icon (i) to get all the Input voltage limits for the selected inverter.

Highest STC Rated Configuration

If necessary, Fronius SnapINverters can back off an array's Max Power Point (MPP) of it's I-V curve to avoid over-current. This allows the warrantied array size to be a 150% DC:AC ratio (exception is Symo 15.0 208 at 140% limit). The maximum AC output is limited to the nominal rating of the inverter selected. That said, due to typical DC derating factors (e.g. wire losses, module mismatch, soiling, ILD, etc), it's common to design with a DC:AC of at least 115%. It may make sense to use configurations with higher DC:AC in cases of partial shading, non-optimal orientation, if irradiance of less than $1000/m^2$, or if the array is otherwise non-ideal. However, in some cases it may be more effective to use two smaller inverters instead of one larger one.

Inverter Input Current limits

- The FSC Tool shows PV Module **Imp** and **Isc** values as provided by the manufacturer datasheets. These values determine PV source string and inverter input operating and short-circuit currents, respectively (depending on quantity of combined strings). Note that the **NEC** considers the PV string's maximum current to be Isc x 125%, per 690.8(A), but the FSC Tool doesn't use this value. If your site will sometimes result in current greater than during STC, adjust current calculations accordingly.
- All transformer-based inverters don't have a current input limit; the MPPT will move the power point along the I-V curve to keep the current from getting too high. In essence, it is this and the power limit that prevent too much voltage and current in design.
- Transformerless inverters (Primos and Symos) have current limits in two senses: the lower limit is termed the **Maximum *Usable* Current**. This is an operating current value that appears in square brackets above the configuration Matrices. Current above this level will result in some clipping of power by bucking current and boosting voltage somewhat. The upper limit is this value times nearly always 150% (1.5) and is termed the **Maximum *Permitted* (or Warranted) Current**. This is effectively going to be a short-circuit current (combined string Isc) and <u>any current above this value will invalidate the Inverter warranty</u>.

Matrix Selection Buttons

Each button selection provides a color indicator of inverter efficiency and an STC DC power rating.

Button Color	Indication	Explanation
Salmon Red	*String is shorter than recommended*	String STC voltage < inverter Minimum MPP Voltage. This is permitted for SnapINverters, but will result in less inversion efficiency. The impact to inversion loss can be mitigated if there are two MPPT's and only one has such short strings.
Yellow-Green	*Array May Be Undersized*	These string configurations allow efficient inverter operation but don't take full advantage of the selected inverter's power handling. This range is often used if the array will be installed in phases over a few years or in very hot conditions that would over-stress a smaller inverter.
Green	*Optimal Array Size*	These string configurations are ideal for the selected inverter (generally about 78 – 118% of AC capacity). Keep in mind, these are general recommendations and should be confirmed as an optimum configuration based on your specific site requirements and the actual inverter selected (see below).

Orange	*Array May Be Oversized*	This configuration can be less inversion efficient (i.e., power clipping can occur) at peak POA irradiation if all arrays are co-planar but may be appropriate if there are cases of partial shading, non-optimal orientation, irradiance of less than $1000/m^2$, or otherwise non-ideal. For the IG and IG Plus, there is no maximum power input limit, but the power output is limited to the values listed in Appendix A. The SnapINverters' power inputs are warrantied to 150% of their rated outputs (140% for the Symo 15.0-3 208). In cases where the power is too high to convert it all, the unit will operate off the MPP value of the array and convert as much of the array power as possible.
Violet	*Combined Strings' Current may Exceed MPPT Usable Limit*	*Only shown for SnapINverter line*. In a STC environment, the array(s) will produce more current than the MPPT Channel can convert and thus the maximum power point on the I-V curve will shift to higher voltage. To the extent clipping is acceptable, this is not a problem for the inverter; to the extent irradiance achieves 1,000 $Watts/m^2$, clipping may occur.

Below are the starting and ending ranges for the **Green** section of inverter series:

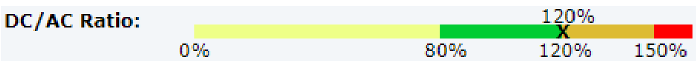
- SnapINverters, CL, IG Plus Advanced: **80%** to **118%** of AC Capacity
- IG: **75%** to **118%** of AC Capacity

Selected Configuration Output Information

After selecting a string configuration(s), information on the selected configuration appears below the configuration matrix. If the project is in the United States and you have selected an NEC Edition, click on the NEC Rapid Shutdown Solutions button for help on providing Rapid Shutdown for the selected configuration. In addition, a graphical DC/AC Ratio bar appears for the complete system size.

DC/AC Ratio

The DC/AC Ratio equals the Total DC Power / The maximum AC output for the selected inverter and voltage. For example, if there are 20 PV modules of 300 Watts, the Total DC power = 6,000 W. If you then select the *Primo 5.0-1 (208V/240V)*, the maximum AC output = 5,000 W. So the DC/AC ratio = 6,000 / 5,000 = 1.20 = 120%:



Note that for inverters that have more than one AC grid voltage setting, the maximum AC power output might vary.

MPPT Configuration Output

The following information is provided to explain the configuration output specifications

Single MPPT Output

Specification	Example	Note
# strings of # modules	**3** String(s) of **10** Modules	*Self-explanatory*
	Current Ratings (Amperes)	
Imp @ STC	**24.0**	*Combined STC operating current input to MPPT*
Isc @ STC	**27.0**	*Combined STC short-circuit current input to MPPT*
Maximum **Isc** [NEC 690.8]	**33.8**	***Isc** @ STC * 1.25*
	Voltage Ratings (Volts)	
Minimum **Vmp**	**324**	*Estimated operating voltage at **Average hottest** PV module temperature and other expected derating factors**
Vmp @ STC	**385**	*Operating voltage at STC*
Maximum **Voc** [NEC 690.7(1)]	**510**	*Open Circuit voltage at STC during Expected Coldest ambient temperature*

* This includes a 3.5% voltage loss for module mismatch, ILD, and circuit resistance.

Dual MPPT Output

Same as above but for each MPPT.

Print Versions

For more detailed configuration output data, please click the Full Configuration Report button. A different report is generated depending on whether there is one or two MPP Channels for the string configuration. This report opens in a new tab in the current browser. You can print the report by issuing a Print command with a keyboard shortcut (Ctrl-P in Windows; ⌘+P for Mac OS) or using your browser's File/Print menu.

If you have a PDF print driver (or other file type print driver), you can save the report as a one page file.

Regardless of which report you create, you will be prompted to specify the AC voltage if the inverter power profile you selected has more than one possible AC voltage. For example, the profile for the Primo 6.0 has 240 V and 208 V setups. When clicking on the Configuration Report button, you will be prompted to enter which voltage applies. The report will show that voltage along with the minimum OCPD rating recommended for that AC voltage. However, for the Primo 8.2 there are separate power profiles for the 208V and 240V and thus you will not be prompted because there is only one possible nominal voltage for each one.

Single MPPT Design

Available in English and Spanish

Dual MPPT Design

Available in English and *partial* Spanish

Appendices

Appendix A – Older Inverter Series

No longer manufactured models but replacement parts are available.

Symo	10.0-3 208-240	9,995	3 Φ (3 phase)	200-600 V	MPPT-1: 25 A / 37.5 A MPPT-2: 16.5 A / 24.8 A Inverter: 41.5 A / 62.3 A
	12.0-3 208-240	11,995			
	10.0-3 480	9,995	3 Φ Wye 480 V only	200-1,000 V	MPPT-1: 25 A / 37.5 A MPPT-2: 16.5 A / 24.8 A Inverter: 41.5 A / 62.3 A
	12.5-3 480	12,495			
	15.0-3 480	14,995			MPPT-1: 33 A / 41.3 A MPPT-2: 25 A / 37.5 A Inverter: 51 A / 67.5-76.5 A
	17.5-3 480	17,495			
	20.0-3 480	19,995			
	22.7-3 480	22,727			
	24.0-3 480	23,995			

Galvo line of single-phase, transformer-based SnapInverters

Galvo	1.5-1	1,500	208, 240 V 1 Φ (Single Phase)	120-420 V	None; MPPT will buck current as needed
	2.0-1	2,000			
	2.5-1	2,500		165-550 V	
	3.1-1	3,100			

IG Plus series **of 1 and 3 phase, transformer-based inverters**

Inverter	**Max AC output** (W) @208 @240 @277	**Nom AC output** (W)	**AC Voltage**	**DC Input Voltage**
IG Plus 3.0-1 UNI	All 3,000	3,000	208, 240, 277 V 1Φ	230-600 V
IG Plus 3.8-1 UNI	3,750 3,800 3,800	3,800		
IG Plus 5.0-1 UNI	All 5,000	5,000		
IG Plus 6.0-1 UNI	All 6,000	6,000		
IG Plus 7.5-1 UNI	6,800 7,500 7,500	7,500		
IG Plus 10.0-1 UNI	All 9,995	9,995		
IG Plus 11.4-1 UNI	10,800 11,400 11,400	11,400		
IG Plus 11.4-3 Delta	10,800 11,400 n/a	11,400	3Φ 208, 240 V	
IG Plus 12.0-3 WYE277	n/a n/a 12,000	12,000	3Φ 277 V	

IG series (Single Phase only)

Inverter	**Max AC output** (W)	**Nom AC output** (W)	**AC Voltage** (W)	**DC Input Voltage**
IG 2000	2,000	1,800	240 V, 1Φ	150-500 V
IG 3000	2,700	2,500		
IG 2500-LV	2,350	2,150	208 V, 1Φ	
IG 4000	4,000	4,000	240 V, 1Φ	
IG 5100	5,100	5,100		
IG 4500-LV	4,500	4,500	208 V, 1Φ	

Appendix B – Extreme Temperatures

The FSC Tool provides links to three databases on separate websites, each providing statistics on extreme temperatures at specific weather stations. These links are available via the information icon ⓘ shown next to the Ambient Temperatures heading.

Each website is explained below, pros and cons. For each website, we show how to get the *Extreme Coldest* and *Average Hottest* temperatures and we pretend our installation site is at 24662 Co Rd 102, Davis, CA 95618 (*this happens to be the PV USA Solar Test Site where many past and some current solar testing is done*).

Solar ABCs

The Solar ABCs' website, an unsecured site hosted by the Florida Solar Energy Center, provides an interactive map for selecting a location and receiving ASHRAE statistics on *Extreme Temperatures*.

Find the nearest location and click on its pin to display the temperature data. In our example of a site in Davis CA, the Sacramento Metropolitan Airport weather station was selected:

SACRAMENTO METROPOLITAN AP

Elev.	High Temp		Distance above roof			Extreme
	0.4%	2% Avg.	0.5"	3.5"	12"	Min
10 m	41 °C	37 °C	59 °C	54 °C	51 °C	-3 °C

The ASHRAE Extreme Min Temp refers to the expected lowest, not record lowest, based on a few decades statistics. Use either the 0.4% or 2% High Temp (or somewhere in between) for the Average Hottest; the closer your PV array will be to having a POA for direct beam irradiation at solar noon in mid-summer, the higher temperature you should select. Here's the definition of both from the website:

High Temp (0.4%): this air temperature is only exceeded during 3 hours (not necessarily continuous) of a summer month (June through August). This number is slightly more conservative than the 2% value.

High Temp (2%): this number is likely exceeded during 14 hours (not necessarily continuous) over a summer month (June through August). The Copper Development Association recommends that this number be used for ampacity calculations.

Both the Extreme Min and the High Temp 2% are likely to be sufficient extremes, but they are less conservative compared to the analogous temperatures found in the next two data sources.

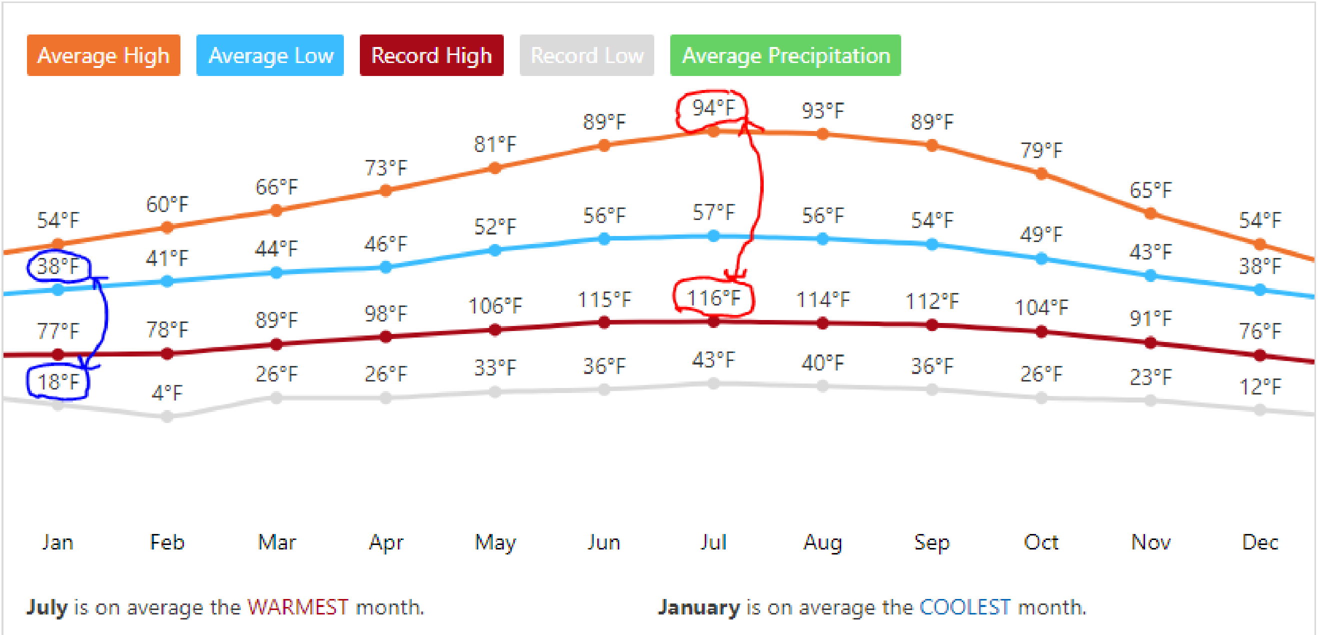
Click here for further instructions and here for the interactive map

Weather.com

If you can't access ASHRAE data for your PV site (weather stations to far away), Go to www.weather.com

Enter your site's zip code (or city) and then click on the "Monthly" sub-menu. Scroll down to find a chart of highs and lows (see example for Davis, CA below). If the chart is not displayed, see 'No Chart Shown' below.

Sample Weather.com chart of highs and lows for Davis, CA



For the Expected Coldest setting, an expected lowest *daytime* temperature is a weighted average of the Average Low and Record Low with latter having twice the weight; else use the Record Low to be conservative. However, in this chart it seems the Record low of 4°F (-15°C) was an anomaly as it occurred in Feb instead of January and it was 37° lower than the Feb Average Low (compared to January at only a 20° delta). So ignore 4°F and choose a weighted average of 18°F (-8°C), 18°F (-8°C), & 28°F (-2°C). That equals 21°F (-6°C)

For the Average Hottest, it's just the mean average of Average High (94°F) and Record High (116°F) or 105°F (41°C). Note that these two highlighted values are also derived for the same site in the next data source.

No Chart Shown

If no chart is shown, you should at least be able to see the Warmest and Coolest months:

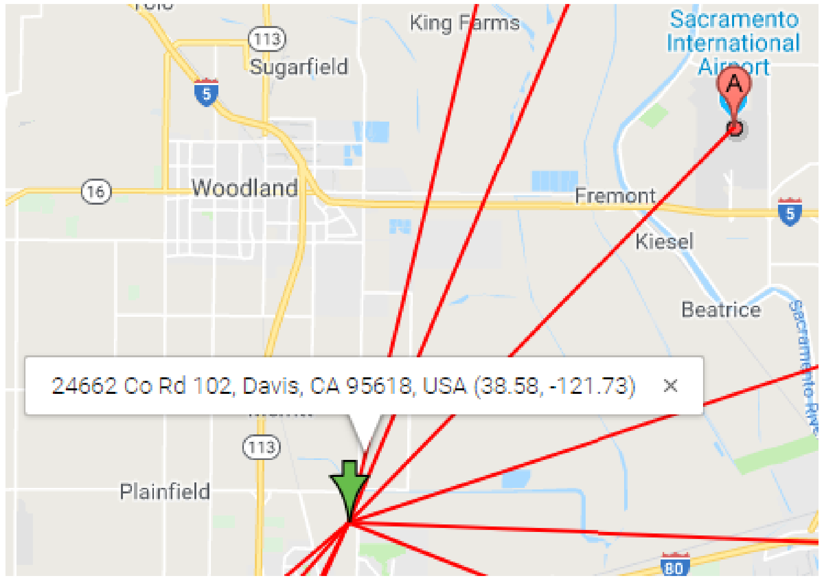
July is on average the WARMEST month. **December** is on average the COOLEST month.

You can then look at each of those months from the month selection list atop the monthly temperature calendar and see the Average and Record Lows to the right side.

ASHRAE – METEO Site

This is a great site as long as you realize it is unsecured and the author does not reveal his/her identity other than a gmail account. That is, it doesn't provide a private connection. Just don't provide any private information; only the city, zip, or address of the PV site. Using the 2017 database (most recent data), the PV USA Solar Test site is 18km from Sacramento International Airport.

The SAC airport Extreme Annual Design Conditions has this data for dry-bulb (DB) temperatures:



Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature							
Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
-3.4	**41.3**	**2.3**	**1.2**	**-5.0**	**42.2**	**-6.3**	**42.9**	**-7.6**	**43.6**	**-9.2**	**44.4**

- the Average Hottest could be set at 41°C (or a degree less per the standard deviation allowance)
- the Expected Coldest for a system lasting at least 20 years would be -8°C but this is conservative on two accounts:
  - it's likely warmer during the daytime of the coldest day
  - An aged system will lose voltage over time.

So even 10 years out (-6°C) is conservative. Consider combining these last two points IF your string sizing would be enhanced by raising the Expected Coldest to -5°C (the 5 year statistic).

Appendix C – Temperature Selection Lists

Expected Coldest Values and Max Voc

The *Expected* Coldest ambient temperature selection list ranges from -40°C to +13°C. The inverter should not be installed in an environment that can get colder than -40°C (-40°F). The NEC 690.7(A) requires using the module's beta coefficient (Voc Coefficient of temperature) if it's available; all modules herein have that coefficient. So the Max Voc is based on the coldest temperature and that coefficient.

Average Hottest Ambient Temperature vs Solar Module Temperature

Hot ambient temperature and high irradiance make for hot solar modules. Hot solar cells have lower Vmp which could dip below the inverter's minimum operating voltage. The actual solar cell temperature is higher than the ambient temperature selected. This particularly true for arrays that are flush-mounted to a roof because the temperature near a roof surface is higher than the site ambient temperature. So how much hotter the solar cell is than the ambient temperature is dependent on how far the module sits above the installation surface. See the next section for more detail.

Air Gap

Solar cell temperature is dependent on the height of PV module above installation surface (aka “Air Gap”). The Mounting Method selection options works well for *flush-mounted* arrays that average a 2.5-5.5” Air Gap. For array Air Gaps outside this range, consider the following *Average Hottest* temp selection:

- ~2” Air Gap: select next higher Ambient temperature
- ~6” Air Gap: select next lower Ambient temperature
- >=7” Air Gap: select the Tilt-up racking Mounting Method

If the PV Arrays are on a roof but are tilted such that the average Air Gap is greater than 18”, select the Single-axis tracker option.

Appendix D – Voltage and Temperature Calculations

Module String Open Circuit Voltage at Given Module Temperature

The module manufacturer provides two key metrics in module datasheet for calculating open circuit voltage (Voc) at different module temperatures:

- **Voc** @ STC
- Temperature Coefficient of Voc (**Beta Voc** or **βVoc**)

Voltage is *inversely* proportional to module temperature: Voc increases as module temperature decreases and vice-versa. Voltage is also *linearly* proportional to module temperature: each 1°C change in module temperature results in a consistent percentage change in Voc. The Voc @ STC provides the starting value and the Beta Voc states this percent change in the Voc with each 1°C change in module temperature.

The formula for module Voc at a given module temperature (T_{MOD}):

$$V_{\mathrm{OC}} = V_{\mathrm{OC@STC}} \times \left(1 + \beta V_{\mathrm{OC}} \times (T_{\mathrm{MOD}} - 25°\mathrm{C})\right)$$

To get the estimated module *string* Voc, multiply the above result by the number of modules in the string.

Determining PV Module Average Solar Cell Temperature

The preceding formula requires an estimate of the average module temperature. For the purposes of providing string sizing options, only the temperatures at *Expected* Coldest and *Average* Hottest ambient temperatures are necessary.

Relevant Coldest Module

At the Expected Coldest ambient temperature, the module temperature is assumed to equal the Expected Coldest value because the coldest temperature is expected at sunrise when the module has not had a chance to heat up from the incident radiation.

Relevant Hottest Module

At the Average Hottest ambient temperature, the module temperature exceeds the Average Hottest temperature because the sunlight has heated the module directly from global irradiation and indirectly by heating the structure/earth around it which radiates heat energy at the modules.

FSC Tool determines the air temperature around the modules based on the Mounting Method selected. See Mounting Method etc. for more detail.

List of Abbreviations and Acronyms Defined

Electrical

• Voc (or VOC)	Open-circuit Voltage
• Vmp (or VMP)	Operating Voltage at Maximum Power
• Isc (or ISC)	Short-circuit Current
• Imp (or IMP)	Operating Current at Maximum Power
• βVoc	Beta temperature coefficient of Voc
• Pmp (or PMP)	Power at Maximum Power (along I-V curve)

Other

• STC	Standard Test Conditions
• βVoc	Beta temperature coefficient of Voc
• NOCT	Nominal Operating Cell Temperature
• NMOT	Nominal Module Operating Temperature
• MPPT	Maximum Power Point Tracker/Tracking

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