

Tech Tip

Morningstar Solar Controller System Sizing with 60 Cell Modules (PWM & MPPT)



ABSTRACT: This Tech Tip discusses the use of today's 60 cell PV modules with Morningstar's solar controllers. It explains why 60 cell modules are not well adapted for meeting the nominal array voltage requirements of PWM controllers. It also shows how Morningstar's MPPT controllers can be used with great success at higher input voltages.

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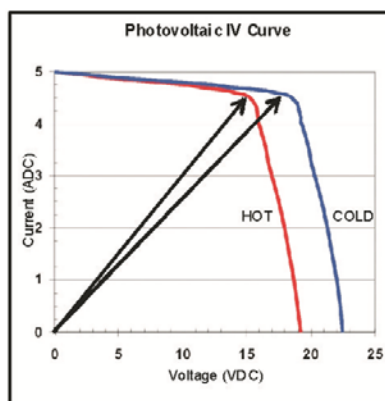
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The Origins of Off-Grid Modules

In the beginning there was Off-Grid (OG) Solar. Photovoltaic (PV) modules were connected to batteries and the batteries were charged. Several methods were developed to manage charging current in order to prevent overcharging the batteries. In 1997, Morningstar's patented Pulse Width Modulation (PWM) Series switching became the best, most reliable way to complete the absorption charging cycle and prevent overcharging.

For many years PV module manufacturers designed their modules for battery charging and it was determined that the best ratio of solar PV cells in Series to battery volts was 36 cells: 12V. The PV module voltage must always be at a higher voltage than the battery for charge current to flow from the module to the battery. Since each PV cell has a voltage of 0.5V, this ratio of 18V to a 12V battery was considered to be optimal since it would always be high enough to provide charging when taking into consideration voltage drop and high temperature conditions. The table below illustrates the battery and PV voltages and shows how the V_{mp} is always high enough with "Nominal Voltage PV Arrays". The "Minimum V_{mp} " row also shows that even in extreme heat, the PV module will always successfully charge the battery.

Nominal System Voltage	12 Volts	24 Volts	48 Volts
Nominal Battery Voltage Range	11V - 15V	22V - 30V	44V - 60V
Nominal Solar PV V_{mp} (STC)	17V - 18V	34V - 36V	68V - 72V
Minimum V_{mp} @ 40 °C	~15V	~30V	~60V



Additionally take note of the module performance IV curves for a 12V nominal PV module. It shows that under the hottest conditions the voltage is still high enough to provide charging current for the batteries.

- **red curve = hot conditions**
- **blue curve = cold conditions**



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Along Came Grid-Tie (Before the Advent of MPPT Controllers)

With the growth of Grid-Tied (GT) Solar, PV module manufacturers were no longer constrained to providing “Nominal Voltage PV” modules for charging batteries. The 36 cell (12V nominal) and 72 cell (24V nominal) modules became less common. The GT market saw the introduction of higher voltage PV modules from thin film module manufacturers as well as the roll-out of 60 cell PV modules, which quickly became the most common module configuration. These higher voltage PV modules made sense when they were stacked in Series for connecting to the grid and selling back at 240V, but they were less ideal for battery charging systems. This mismatch of voltages and functionality spurred the following two questions from the field:

- 1) *Can I use 60 cell PV modules to charge a 24V battery system that uses a PWM controller?*

Morningstar does not recommend using 60 cell modules for charging a 24V battery system with a PWM controller.

Even though these modules have a V_{mp} of 29-30V, which seems enough for charging 24V batteries, the system will typically have marginal performance. After correcting for warmer temperature conditions, the V_{mp} will be well below battery regulation voltage levels. Thus, the batteries would not be able to reach a full charge and will miss out on the most important charge stage—the absorption stage. Such undercharging for extended periods of time will greatly reduce the life of the batteries.

- 2) *Can I use two 60 cell PV modules in Series to charge a 48V battery system that uses a PWM controller?*

Morningstar does not recommend using two 60 cell modules in Series for charging a 48V battery system with a PWM controller.

While two 24V nominal PV modules in Series is acceptable for use with a 48V battery bank, two 60 cell modules in Series will not have high enough voltage to fully charge the batteries in warmer conditions. With a V_{mp} of 60V, this configuration is simply not adequate for charging a 48V battery bank.



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Maximum Power Point Tracking (MPPT) Technology to the Rescue

In 2008, Morningstar introduced the [TrakStar](#) advanced MPPT algorithm technology that maximizes the energy harvest from the PV array into the battery under all operating conditions. This technology innovation is used in Morningstar's [SunSaver MPPT](#) and [TriStar MPPT](#) controllers and has resulted in the TriStar MPPT controller becoming the world-leading MPPT solar controller.



Morningstar's [SunSaver MPPT](#) and [TriStar MPPT](#) controllers have been deployed in a myriad of off-grid industrial, leisure and residential installations around the globe. Their introduction enabled battery-based PV systems to begin using grid-tie PV modules. Morningstar's MPPT controllers keep the PV modules operating at the V_{mp} and ensure that grid-tie PV modules are optimized in voltage. As such, it is now possible to use 60 cell PV modules to charge 12 - 48 Vdc battery systems, as specified on the next page.



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Can I use 60 cell PV modules to charge a 12V, 24V or 48V battery system that uses a Morningstar MPPT controller?

Morningstar recommends using 60 cell modules with MPPT controllers as long as there are enough modules in Series to fully charge the battery bank. The table below summarizes the possible string sizes for 60 cell PV modules in Series when using Morningstar's MPPT controllers.

- For 24V battery banks this means at least two 60 cell modules in Series are required.
- For 48V battery banks it means three or more modules in Series are required.

System Voltage	12V	24V	48V
SunSaver MPPT	1 in Series	N/A	N/A
TriStar MPPT	1, 2 or 3 in Series	2 or 3 in Series	3 in Series

- Note that **maximum Voc voltage** is typically too high:
 - For two 60 cell modules in Series for a SunSaver MPPT controller (Max Voc = 75V).
 - For four 60 cell modules in Series for a TriStar MPPT controller (Max Voc = 150V).
- To check the maximum Voc of the array, Voc should be calculated for the record cold temperature at the installation site. Higher record cold temperatures may allow for more modules to be safely wired in series.
- Please use Morningstar's [string sizer](#) to check the effects of temperature for proper sizing.