PERC Cell Technology & Half Cell Solar Modules: How Efficiency Gains and Cell Layout Yield Greater Charge Controller Output

Introduction

PV modules continuously improve through R&D efforts that contribute to incremental efficiency gains and reductions in cost. The industry then directly reaps these benefits each year. Occasionally a technology change takes a larger, more significant step that is worth taking note of. One such change was the introduction of Passivated Emitter and Rear Cell Technology (PERC) which significantly increased cell current and voltage (and in effect, maximum module voltage). In addition to this, there has been a large influx of half cell modules on the market. These half cell modules include an innovative cell layout that can provide even better performance than with traditional full cell modules. With a focused look at how solar power electronics can take advantage of these changes, we can make smarter system sizing decisions and leverage these new developments most effectively in off-grid solar systems where every watt matters.

How are New Solar PV PERC Modules different?

Half-cell modules have made a comeback

PERC PV cell technology has rapidly become the dominant cell technology in the market.

Many manufacturers are also offering these PERC modules in a half-cell configuration. Unlike small modules which use half-cells to achieve a smaller overall form factor and meet low wattage needs in the market, these new configurations are the same size as whole cell modules but contain twice as many half-cells to achieve the same ratings but with some unique benefits. Below are the relative new configurations:

36 full-cell ~ 72 half-cell
60 full-cell ~ 120 half-cell
72 full-cell ~ 144 half-cell

Half-cell modules have slightly higher efficiencies due to lower current in each cell and have higher voltage ratings than full-cell modules.

Besides these new cell configurations, Vmp and Voc voltages of PERC modules are ~5-15% higher than that of traditional modules. Table 1 below shows a comparison of voltage ratings between traditional modules and new PERC modules at standard test conditions.

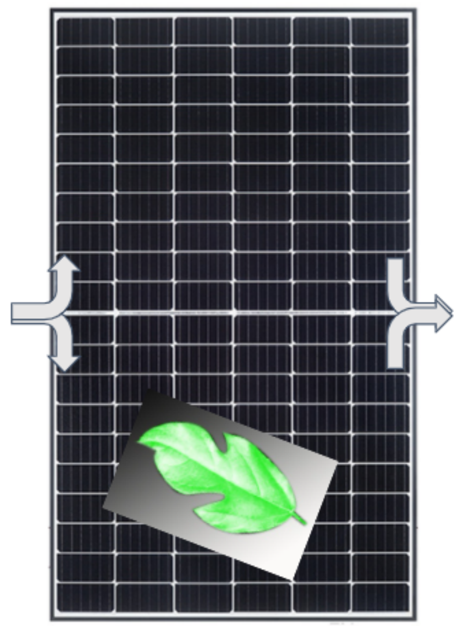
Table 1: New Perc Module Voltages

# of Cells	36 Cell / 12V Nominal		60 Cell		72 Cell / 24V Nominal	
Old/New	Older	New PERC	Older	New PERC	Older	New PERC
Vmp	18V	19-21V	30V	31.5-34.5V	36	38-42V
Voc	22-23V	23-25V	36-37.5V	38-42V	44-46V	46-50V

Partial Shading Benefits of half-cell module layouts

Partial shading of solar modules has always been a major concern with solar PV systems. For off-grid systems it is especially important to get as much charging as possible in order to maintain loads and extend the lifetime of the battery. This is where using half-cell modules can really make a difference.

- Half-cells have the same voltage as full-cells but 50% of the current.
- Modules are made up of 2 parallel strings of half-cells which is similar to 2 modules wired in parallel
- Shading one side of the panel only affects 50% of the current of the module allowing the module to operate with full voltage with at least 50% current
- Partially shaded half-cell modules can provide enough voltage to support charge controllers in cases where full-cell modules do not.
- An MPPT controller can allow the full current with a lower voltage with some bypass diodes activated within limits.
- Better MPPT tracking can result with half-cell modules with higher array voltage levels



Partial shading with a whole cell module acts like a bottle neck limiting the current of the entire panel. With partial shading, the half-cell module can still operate with full voltage and at least 50% of the module current from the unshaded half of the panel. This can often be much better than having the partial shading affecting 100% of the current.

As these points show, the ability of half-cell modules to operate at full voltage and at least half of the current can make a significant difference allowing more charging when there is partial shading. This additional power can be critical for systems that may have partial shading that lasts for longer periods.

How does this affect array sizing with solar controllers?

Meeting the voltage requirements for a PV array is one of the most important considerations with string sizing calculations. The 5-15% higher voltage ratings of the new PERC modules can have a big effect on this.

- 36 cell and 72 cell PERC modules have higher voltage ratings than what was considered to be the standard with traditional nominal voltage modules in the past.
- 60 cell PERC module voltage ratings are now just a few volts lower than that of traditional 72 cell modules.

Table 2: Summary of System Sizing with PERC Modules

Type of Module	PWM Sizing	MPPT Sizing
36 Cell and 72 Cell Modules	Higher voltage than needed	Higher voltage works well
	Lower % of Pmp power utilized than before	Significantly higher MPPT Boost than before
60 Cell Modules	High risk of marginal performance	No risk with higher voltages
	Not recommended	Recommended

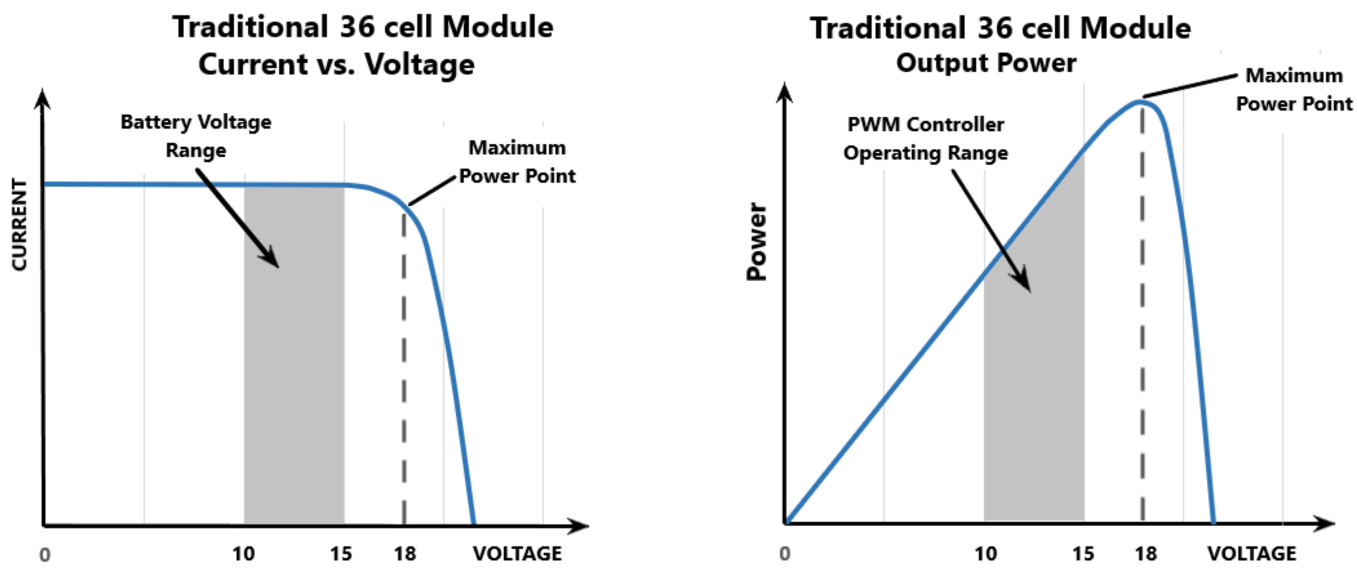
36 cell and 72 cell PERC "nominal voltage" modules

One of the advantages of using MPPT controllers instead of PWM controllers is "MPPT Boost"--the extra power achieved by operating at the maximum power voltage (Vmp) compared to a PWM controller which operates in the lower battery voltage operating range.

- 36 and 72 cell PERC modules can still be used at nominal voltage with an equivalent matching battery voltage of 12V or 24V respectively, with both PWM and MPPT controllers.
- MPPT Boost gains are now even more significant compared to a PWM controller.
    - MPPT Boost vs PWM is ~5-30% with traditional modules
    - MPPT Boost vs PWM is ~15-55% with PERC modules

While it is possible to use PWM controllers with new 36 cell and 72 cell PERC modules, the increase in MPPT boost associated with PERC modules position MPPT controllers to be even more economically attractive than before. The graphs that follow illustrate the additional MPPT boost attained from new modules compared to older modules.

Figure 1



This first pair of graphs in Figure 1 depict a traditional module operating at its rated Vmp voltage. You can see that the power shown at the Vmp voltage of 18V attained by an MPPT charge controller is greater than the power generated by a PWM controller with an operational voltage range of 10-15V.

Figure 2

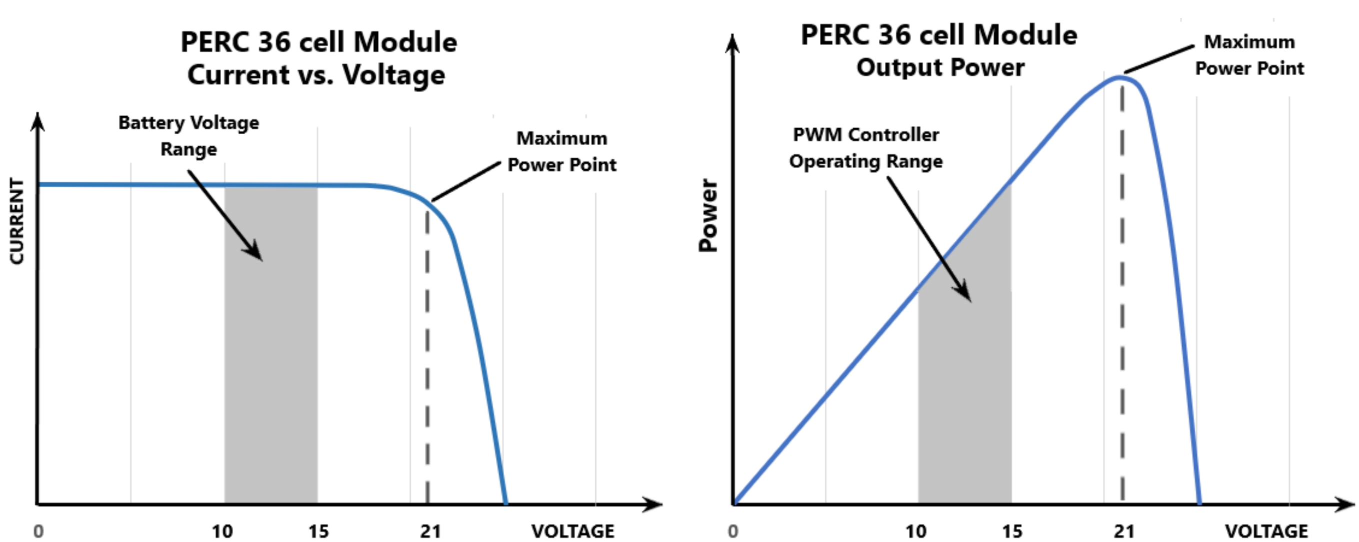


Figure 2 above illustrates the performance of a new PERC PV module operating at its rated Vmp voltage of 21 volts.

The MPPT boost with these new 36 and 72 cell PERC models is significantly higher than what we have seen before. The voltage vs. power graph shown here has a higher MPPT voltage of 21V compared to 18V in the previous graphs. With these higher voltages, the MPPT boost will be approximately 15 to 55% which is a significant gain over traditional modules. The higher the Vmp rating is, the higher the MPPT boost will be.

Sizing Example 1: New 72 PERC Cell Module with a 24V System

- Voltage ratings (STC) : Vmp = 41.3V; Voc = 49.3V
- Historic Temperatures: Record Low = -10°C/14°F, Average High = 35°C/95°F
- Module Voltage Calculations
    - Min Vmp @ +35C = 36.7V,
    - Max operating Vmp = 42.8V
    - Max Voc @ -10C = 54V
- Comparative MPPT boost calculations during bulk charging with battery voltage = ~28V
    - MPPT Boost: PERC module = ~ +25% (warmest ave high) to +50% (coldest operational)
    - MPPT Boost: traditional module = ~ +5% (warmest ave. high) to 30% (coldest operational)

In Sizing Example 1, the minimum operational Vmp is as high as the standard (STC) ratings of most traditional modules. This is significant considering that this example has such a high annual average high temperature. The PERC cell based module's voltage ratings have all but eliminated the negative impact of this high temperature on module voltage. A significant advantage!

Array sizing with new 60 cell PERC modules

As indicated in Morningstar's 60 Cell PV Module Sizing Tech Tip, traditional 60 cell modules are not well adapted for meeting the nominal voltage array requirements for PWM controllers. This is because the Vmp voltage can drop too low with higher PV cell temperatures, causing marginal performance and preventing the battery from getting fully charged. Some customers may be tempted to now consider using 60 cell PERC modules in place of 72 cell modules in nominal-sized systems, especially with PWM controllers. One should exercise extreme caution and be aware of the possible consequences before deciding to use a 60 cell PERC module with a PWM controller.

> *Important! - Please be aware that it is the customer's responsibility to make array sizing choices and Morningstar does not guarantee the performance of the system when using our online String Sizing Tool. The tool uses data provided by other parties (such as PV module specs) and makes calculations based on reasonable assumptions which Morningstar cannot always verify*.

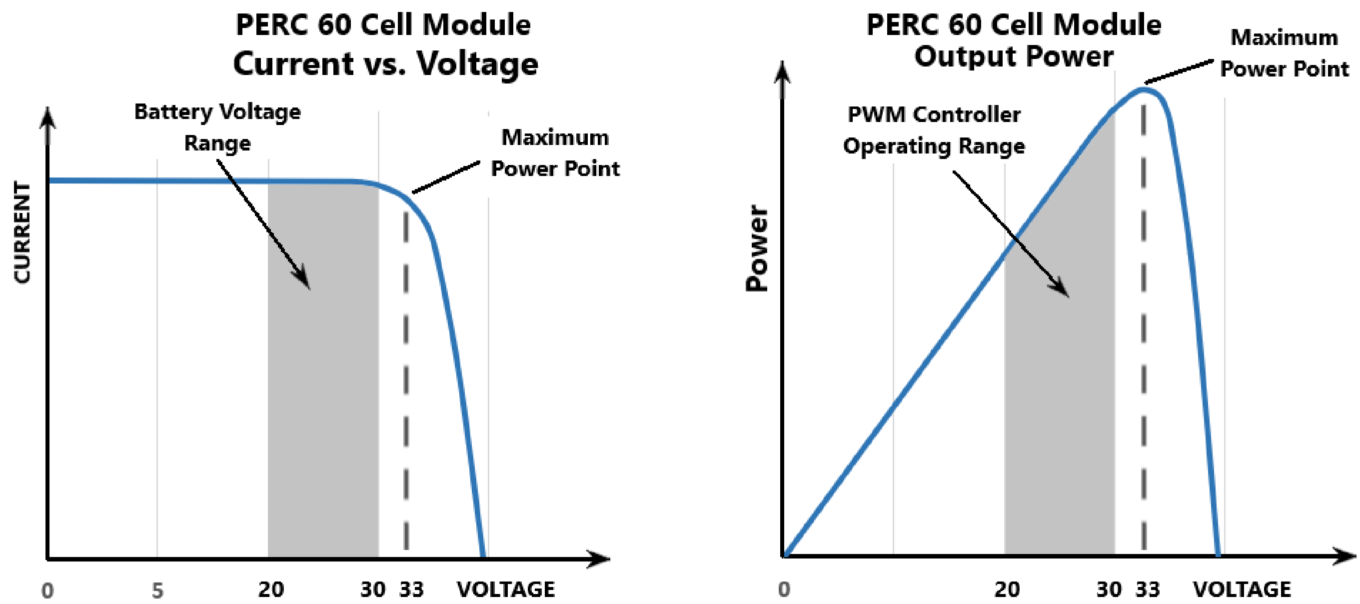
The following factors reduce the risk of marginal performance when sizing a 24V or 48V PWM system with 60 cell PERC modules.

- Higher Vmp ratings
- Lower max regulation voltages; For sealed, AGM or GEL batteries; Not for Flooded batteries
- Climates with lower average max temperatures
- Systems deploying lithium batteries that can tolerate extended periods at a partial state of charge

Morningstar's string calculator can help evaluate the use of a 60 cell PERC module with a PWM controller and a 24V or 48V nominal voltage system. The string calculator results warn "marginal performance in high-temperature conditions" when the PV voltage might be insufficient for battery charging. To provide additional assurance, a higher max battery voltage, and a higher average high temperature can be entered into the string calculator to leave some headroom in the design.
The system should also be monitored during the warmest times of the year to verify that the battery is getting fully charged.

Figure 3 below shows graphs of the IV and power curves for a 60 cell PERC module operating at its rated Vmp voltage of 33 volts. The Vmp voltage is not that much higher than the PWM controller's highest operating voltage. When the module voltage reduces due to higher temperatures, the array Vmp may drop below the required voltage setpoints of the controller and charging may be temporarily paused during this period.

Figure 3



The insufficient voltage will be more of a problem with MPPT controllers. You can see from this graph that the lower Vmp voltage results in very little to no MPPT boost. Also, MPPT controllers are DC-DC Buck converters and require slightly higher input voltages than PWM controllers for charging to occur, increasing the risk of marginal performance in warmer conditions.

In accordance with past recommendations, Morningstar recommends using 60 cell PERC modules with MPPT controllers as long as there are enough modules in series to fully charge the battery bank.

- 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.

Table 3 below summarizes series string sizing options for 60 cell PV modules with Morningstar's MPPT controllers.

Table 3: Array Sizing Options with 60 Cell Modules

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

Sizing Example 2: 60 Cell Module for a 24V System

Here is an example of a string sizing configuration with a 24V system and a new 60 cell PERC module which is not advisable.

- Module voltage ratings (STC) : Vmp = 32V; Voc = 39V
- Battery Voltages:
  - Min = 23V,
  - Max = 29.2 + .5V = 29.7V
- Historic Temperatures:
  - Record Low = -10°C/14°F,
  - Average High = 30C + 5C = 35°C/95°F Module Voltage Calculations
- Min Vmp @ +35C = 27.7V, Max operating Vmp = ~ 32.1V
  Note: A 0.5V higher max Battery Voltage and 5C higher Average High Temperature was applied in these calculations for greater assurance.

The minimum Vmp is below the threshold minimum Vmp voltage requirement and will thus trigger our string calculator to display a "marginal performance in hot ambient temperature" warning for a PWM controller. The module in this example should not be used as a 24V nominal module as it would have marginal performance in hot conditions. This risk would be reduced if the max battery voltage and average high temperature were lower. Marginal performance from low voltage can be resolved by deploying a higher voltage string with an MPPT controller

Conclusion

In Summary, PERC cell technology, with its new cell configuration options, delivers more voltage to charge controllers to greatly increase power harvest. This provides more overall gains in Maximum Power Point Tracking systems and provides PWM controllers higher input voltage to improve their charging performance in hot temperatures. Additionally, higher cell-count modules, with their "two-in-one" design, mitigate impacts of partial shading, so modules can continue to provide most of their rated power during these conditions. We hope this technology overview, and the sizing examples we included, help you realize the benefits of PERC technology in your off-grid system designs.

5/3/2021