Sizing Benefits of MPPT Controllers with Nominal Voltage Arrays

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Since it was introduced in 2009, the high-praise earned by Morningstar's TriStar MPPT has been both continuous and consistent: the controller is considered throughout the worldwide renewables industry as one of the most reliable, highest quality controllers made. TriStar's worldwide recognition for delivering proven benefits to the overall performance of battery-based photo-voltaic (PV) solar systems, is due to its high efficiency, advanced state-of-the-art TrakStar MPPT algorithm, and fanless design—unique among higher-powered charge controllers.

One other unique attribute, however, can easily be overlooked: the advantages the design has over other MPPT types. By way of explanation, a brief review of charge controller technology helps. One of the key differences between an MPPT controller and a simpler PWM controller is that the array voltage input tolerance is much higher with MPPT. However, although the input voltage on an MPPT can be higher than that of a typical PWM, the maximum power point tracking's operation is often confined to a voltage window that must be significantly higher than battery voltage.

For this reason, even though a charge controller is theoretically most efficient at lower operating voltages (i.e. close to battery voltage), many MPPT controllers are unable to harvest maximum power from nominal voltage arrays. This can be a costly limitation as there are several benefits to such usage.

Take, for instance, a 48V system. The most common array configuration for use with a PWM controller would include two (2) 72-cell modules in series, per parallel string. As each module would be considered 24V nominal, their combined voltage per string is suited for a 48V battery. However, given the low voltage operating threshold of most MPPT controllers, users would be strongly advised to consider a different and possibly less-than-optimal array configuration.

Morningstar's MPPT controllers, on the other hand, are engineered to impose no such limitation, and in many cases, we encourage these configurations for the optimal performance and cost benefits listed here:

- Better conversion efficiency
- Maximum power harvesting with fewer modules

- Competitive price/watt of 72-cell modules
- Reduced concerns of high DC input voltage
- Low voltage breakers and BOS
- Additional parallel strings may improve tolerance to shading

Let's look at a specific example to illustrate a few of these advantages:

Although many controller manufacturers will provide a single efficiency rating for their MPPT's, the actual power efficiency can vary greatly in response to the input voltage. In particular, when input voltage is closer to battery voltage, less power is lost in the conversion process. Conversely, the greater the distance between input voltage and battery voltage, the greater the amount of power which needs to be converted—that "has to go somewhere." That "somewhere" is heat, with a larger percentage of input power being dissipated as heat during the conversion process.

This effectively means that the operation of most MPPT controllers is limited to a fixed input voltage when they are used with nominal voltage arrays. In other words, the controller has no ability to conserve power and can only limit the amount of post-conversion output current that can flow to the battery. Essentially, it becomes an ordinary DC-DC converter, without variable 'boost'.

Even though conventional MPPT controllers may still be able to turn on and provide a degree of charging at nominal input voltages, the added benefit of "MPPT intelligence" cannot be used at the operating voltages—which is exactly where true power conversion would be most efficient. Therefore, the performance advantage of MPPT cannot be fully maximized with efficient power conversion.

However, Morningstar MPPT's are not subject to this limitation, because they're designed to accommodate optimization of both MPPT and conversion efficiency simultaneously. This means that with a Morningstar, true maximum power harvesting can be achieved from any array.

Because the input turn-on voltage of the controller is the same as the low-voltage threshold of the MPPT operation, the TriStar MPPT can provide the benefit of efficient power conversion at lower input voltages than its competitors. As soon as the controller can begin charging, the MPPT is active; there is no delay in waiting for the MPPT to reach a higher turn-on voltage (even if one were to exist). Not only are these voltage thresholds synchronized, but they are also typically lower than the competition.

The figures below further illustrate this advantage regarding the array configurations and input voltages that are often considered for 48V TriStar MPPT systems.

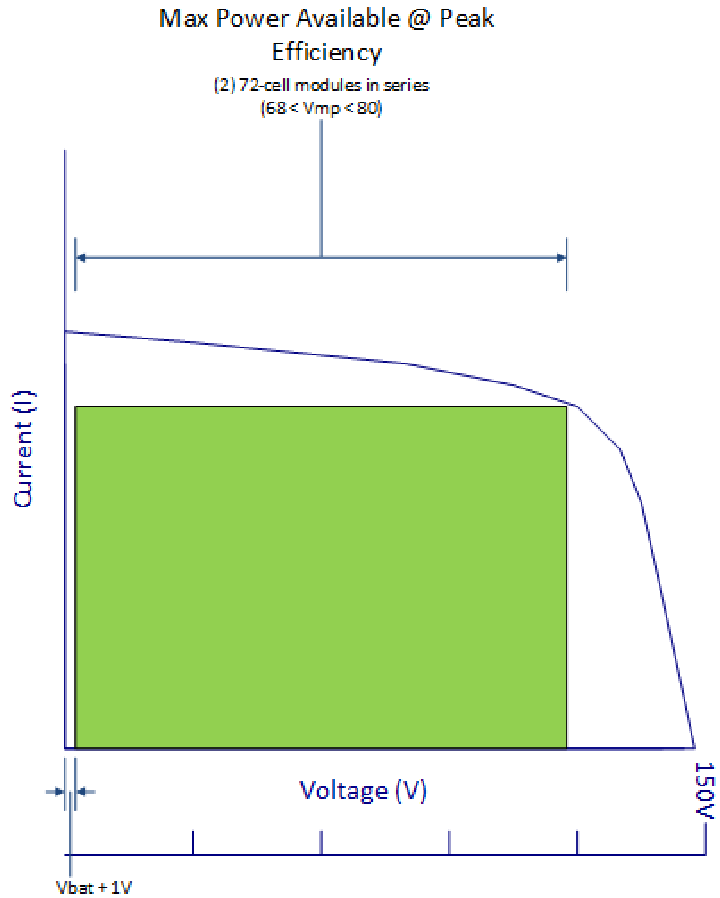

Figure 1:

**Ambient operating temperature range: -30℃ to +30℃*

With Morningstar MPPT controllers, operation will begin with input voltages as low as 1V above battery voltage (i.e. Vb + 1). With many competitors though, charging can't begin until the input exceeds 5V above battery voltage (i.e. Vb + 5). Much of this is due to their use of mechanical relays for reverse current protection, as opposed to the advanced, more precise FET-driven circuitry used in Morningstar controllers. This avoids unnecessary time delays early and late in the day when additional energy harvest may be possible.

Max Power Available @
< Peak Efficiency

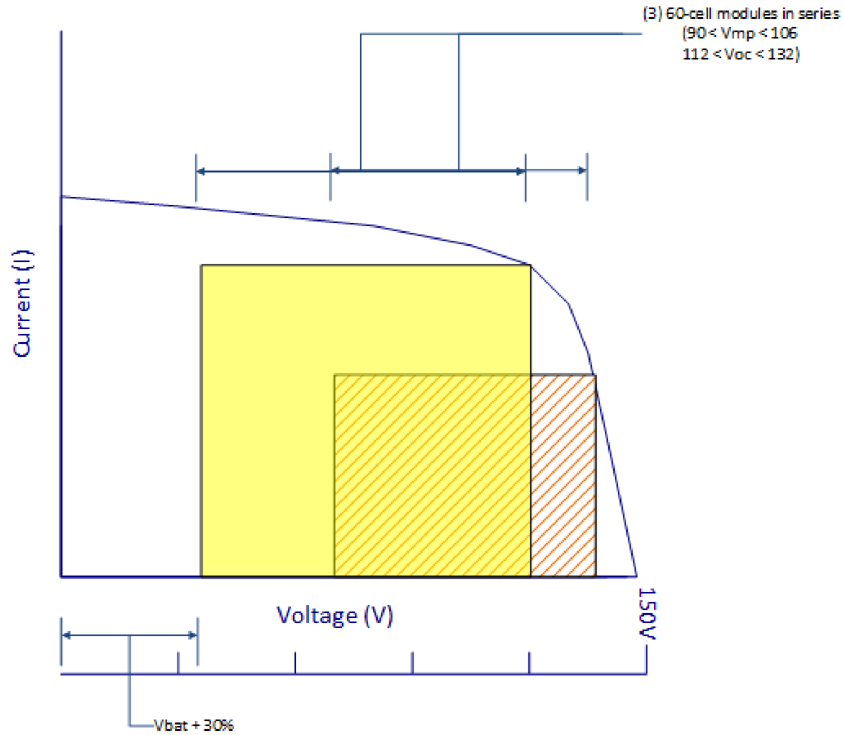

Figure 2:

**Ambient operating temperature range: -30℃ to +30℃*

Furthermore, some manufacturers require a minimum input voltage 30% higher than the battery voltage for the MPPT to function properly. That can also translate into a significant loss of potential energy storage below these operating voltages. For this reason, one can expect better efficiency and power harvesting from a Morningstar MPPT controller when compared to similarly rated products.

Input Voltage May Cause Power Derate/
Risk of Controller Damage

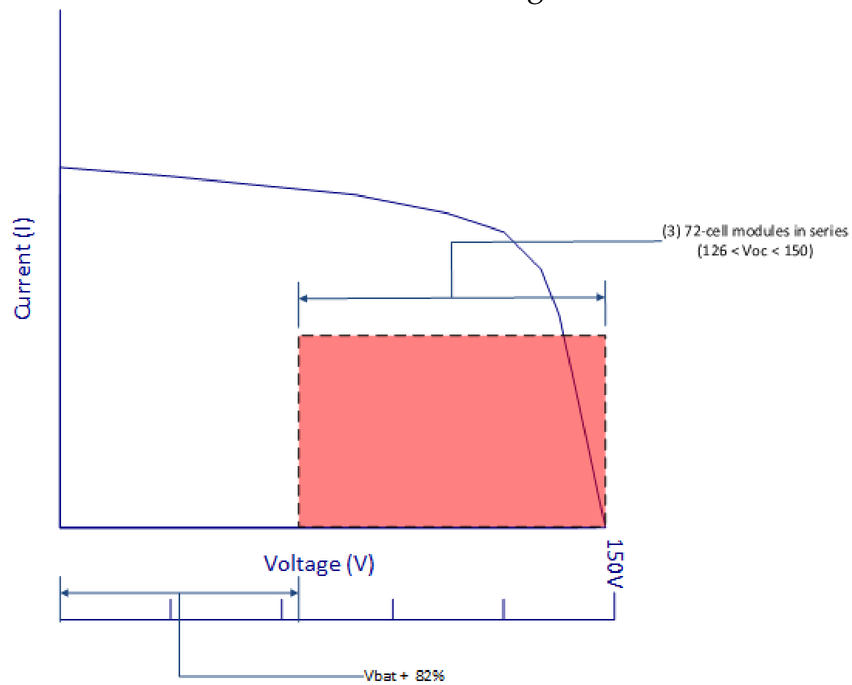

Figure 3:

**Ambient operating temperature range: -30℃ to +30℃*

To elaborate on these advantages, Morningstar's TriStar MPPT controllers offer the flexibility to support the use of popular 72-cell modules for 48V battery systems, without exceeding the common 150V input limit of low voltage charge controllers and disconnects. Contrast that to conventional MPPT's which are unable to optimize production from nominal voltage arrays, because each string would require at least three (3) 72-cell modules in series to effectively convert the power to battery voltage.

Moreover, the resulting array risks damaging the controller in cold temperatures since the open-circuit voltage may rise above the maximum input. For those controllers that offer an inoperable 'safe zone' and can allow the input to exceed 150V, using this feature in an NEC-compliant installation would typically require a 300V input breaker which can be significantly more expensive than a comparable 150V breaker, adding unnecessary cost to the system.

Following along those lines, another notable advantage of supporting two modules per string for 48V systems is that it's much easier to add incremental power and oversize an array in order to compensate for shading or cloudy weather. Many solar installations use pre-fabricated combiners to accommodate a greater number of parallel strings than what might otherwise be used for a given array. The incremental additional cost of adding more strings to a nominal 72-cell array is offset by the reduction in number of modules needed to achieve balanced strings, along with the reduced cost of the associated installation.

Perhaps a lesser known advantage of using the lower voltage array is that, in some regions of the world, installers are required to have a higher level of electrical qualifications to allow them to wire DC voltage in excess of 120V. Because the output of three 60-cell modules in series has the potential to exceed this threshold, especially in cold climates, it might require a more specialized electrician to conduct the installation which can raise installation costs. Since the string voltage of the two 72-cell modules is well below the 120V 'low voltage' operating limit, less expensive labor can be used with fewer safety concerns.

Many manufacturers voice concern over the use of nominal voltage arrays in high temperature environments, counter to the effects of higher voltage on the performance of these systems. Their issue is that the resulting rise in cell temperature levels could cause the input voltage to drop too close to the battery voltage and limit the output power as a result. In particular, much of this anxiety seems to involve the use of older modules with characteristically lower output voltages.

However, as proven by studies of module degradation, the effects of age on module performance are mostly characterized by a reduction of output current as opposed to significant voltage degradation. It is also important to note that the cell temperatures of ground and pole-mounted systems tend to be lower than roof-mounted arrays, due to increased shade and airflow. While temperature factors may still need to be considered in very hot climates, thanks to the ability of Morningstar MPPT controllers to harvest maximum power at lower input voltages than competitors' nominal voltage arrays can still provide ample headroom for many site locations year-round. And while voltage drop should be calculated, especially in systems using flooded batteries, the potential advantages of this configuration are often justified. In cases where high temperatures can be more extreme, PWM controllers are often a more compelling option due to their similar performance and lower cost.

For more information on specific array voltage compatibility and performance, please consult the Morningstar String Calculator (http://string-calculator.morningstarcorp.com) and MPPT operation manuals.