Over-Paneling an MPPT Solar Charge Controller

Warning: Most MPPT controllers allow over-paneling. However, there are a small number of them that do not. Be sure to check the specifics for your controller.

Warning: This paper is about MPPT controllers. PWM controllers are very different and none of what is in this paper applies to PWM controllers.

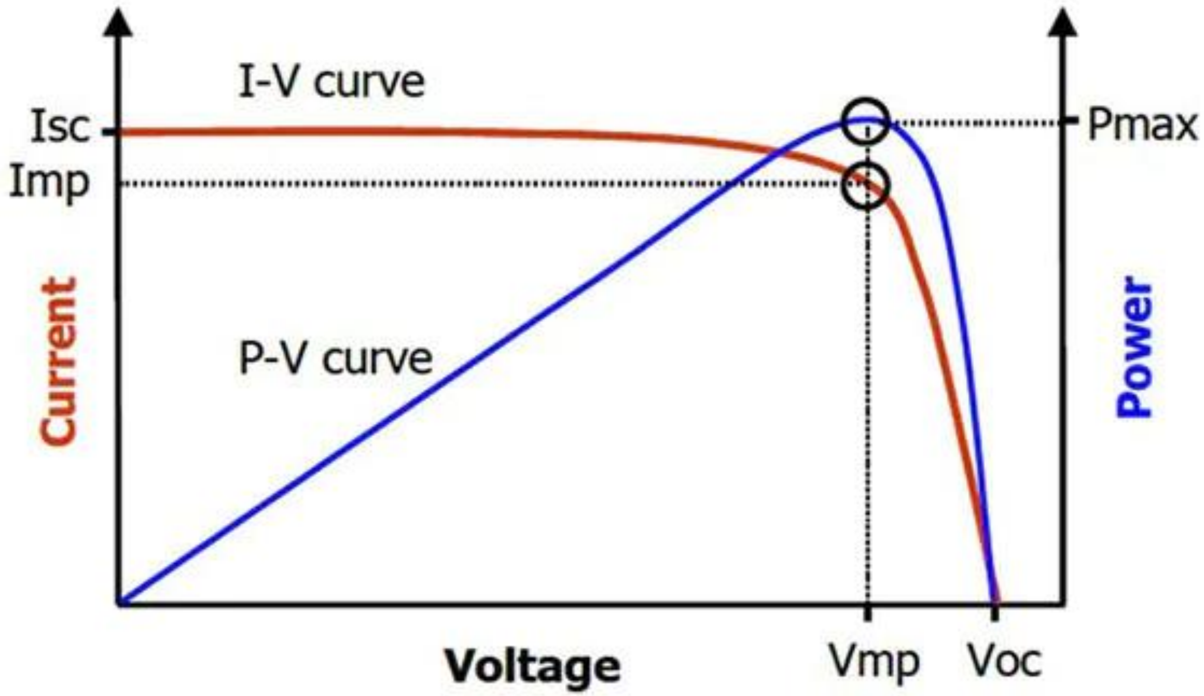
Background: What is Power Point Tracking?

For any given set of light and temperature conditions, a solar panel will have a different current-voltage curve. The point a panel is operating on that curve is known as the 'Power Point'. To get the most possible power out of a panel, the current should be adjusted to the point where the Voltage times Current produces the highest value (Power = Current x Voltage). This is known as the Maximum Power Point (MPP). See the diagram below.

An MPPT controller will occasionally raise and lower the current going through the panel to find the MPP. Since the MPP changes as the conditions change during the day, each time it scans it might find a slightly different MPP to use. By doing the scan on a regular basses, the controller can track the MPP. Thus, the name Maximum Power Point Tracking (MPPT).

When the system can not take the full power from the panels, the controller will move to a less efficient power point. The limit of this is when the battery is full, no power is needed, and the controller stops all input current. This means the voltage will go to Voc and power production will be zero. (0A x Voc =0W)

NOTE: Not all MPPT controllers are alike. Each MPPT controller can have a different algorithm for how it does the scan and how often it does the scan. These differences can make a difference in how well the controller will harvest the power from the solar panels.



What is Over-paneling on an MPPT controller?

Short Answer:
Installing more panel wattage on an MPPT Solar charge controller than the controller is rated for.

Long Answer:
Most MPPT controllers have the following two specs: The Max Input Voltage it can handle and the Max Output Current it will generate. This means that 1) you can not exceed the specified voltage on the input without damage,
and 2) the controller will produce no more than the specified max output current. The output current is used to determine how much power it can pass to the battery (e.g., A 30A output to a 24V LiFEPO4 battery will produce a nominal 27.2V x 30A = 816W) However, with many MPPT controllers, the PV array wattage can be significantly higher than the wattage the controller will pass to the battery. The controller will just not use the power it can't handle.

Why would I want to over-panel? Aren't I wasting power?
There are many conditions when production is lower than desired. A few examples are:

- Cloudy days
- Winter days with the sun low on the horizon.
- Panels often (usually) do not produce at 100% of their rating. It is not unusual to see panels perform at a power level that is 20%-25% less than the STC (Standard Test Condition) ratings.

At these times, a panel array that is sufficient for sunny summer days may become insufficient. By over-paneling, the array can produce more power in sub-optimal situations without using a larger, expensive charge controller.

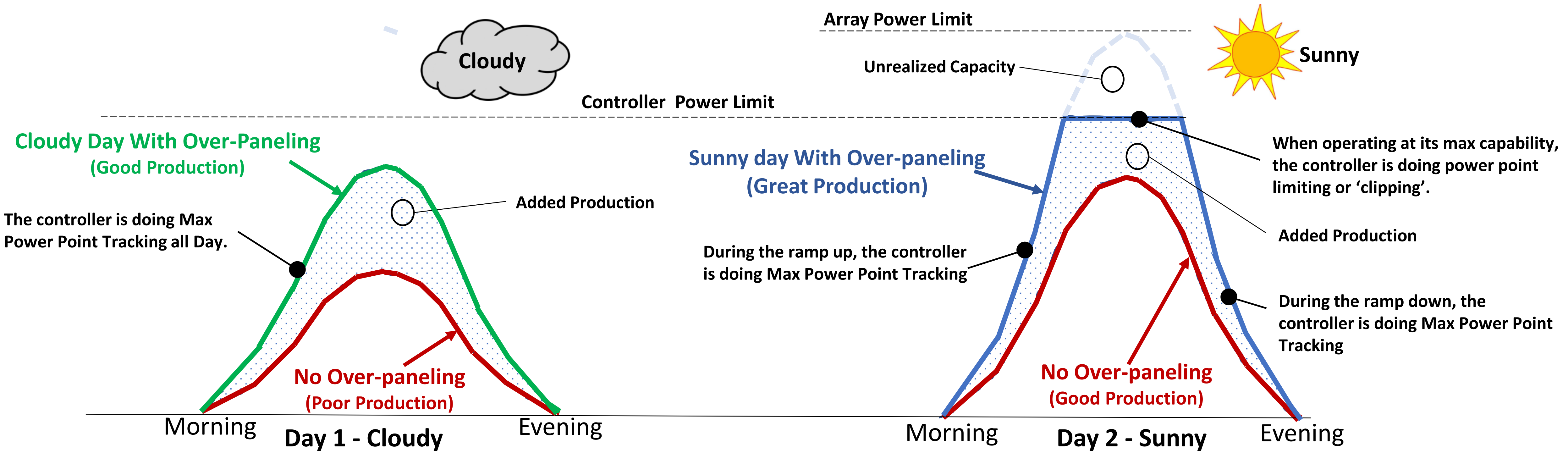
In the past, panel costs were high, and systems were designed to milk every possible watt-hour out of the precious panels. However, the price of panels is now so low that it is now a viable option to over-panel even though some production may be wasted.

How does Over-Paneling work?

An MPPT controller has no direct control over its input voltage, but it can limit the current at the input. When the controller detects that it has reached its max output current, it will start throttling the input current. When the current through the panels goes down, the voltage from the panels will go up and the panel starts operating at a point that is less than optimal. Consequently, the total production of power goes down. Therefore, by controlling the input current, the MPPT controller can limit the power production and power throughput to a level it can handle.

Also note that when limiting the power from the panels, the controller is doing the opposite of Maximum Power Point Tracking (MPPT). It is purposely changing the current to move the Power Point to a less productive setting for the panels. This is also called clipping.

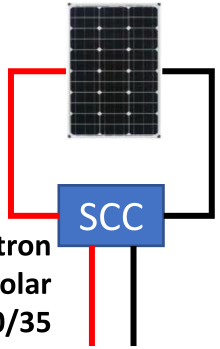
The power production for a cloudy day followed by a sunny day might look something like the image below.



A Practical Example of Over-Paneling

A recent poster on the forum had the configuration shown but needed more production on winter and/or cloudy days.

Sunpower 435-watt panel



Victron SmartSolar 150/35

To 12V system

Panel Specs

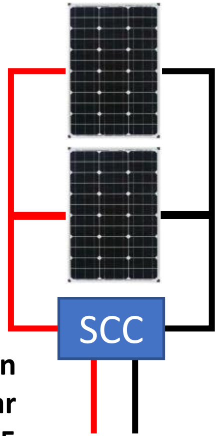
Electrical Data	
	SPR-E20-435-COM
Nominal Power (Pnom)[6]	435 W
Power Tolerance	+5/−3%
Avg. Panel Efficiency[7]	20.3%
Rated Voltage (Vmpp)	72.9 V
Rated Current (Impp)	5.97 A
Open-Circuit Voltage (Voc)	85.6 V
Short-Circuit Current (Isc)	6.43 A

SmartSolar 150/35 Controller Specs

Input Voltage Max	150V
Max Output Current	35A
Power (14Vx35A)	490W
Isc Limit	40A

The person had three additional panels and wanted to use them for cloudy days but was concerned about burning out the controller from too much input wattage. (2 Panels would be 870W, but the controller will only output 490W)

Since the panel Voc is 85.6V, two panels in series would exceed the input voltage limit of the controller. (2x85.6V=171.2V) However, the Voc of 2 panels in parallel would stay at 85.6V.   Therefore, two panels in parallel can be used and not damage the controller.



Victron SmartSolar 150/35

To 12V system

In this configuration, the panels have the capability of producing up to 870W, but the controller would adjust the input current in order to limit power and keep the output current to 35A (490 W)

In fact, all four of the panels could be hooked up in parallel for a possible 1740W, but the controller will limit it to 490W. However, that much excess would be well past the point of diminishing returns.

The hidden Over-paneling limit: Max Array Isc

Some controllers do not specify a direct over-paneling limit, but they do specify a Max Array Isc. This in turn will often limit the amount of over-paneling the controller will support.

In general, the lower the Voc is for an array, the higher the Isc will be for the same wattage. Consequently, the limit on the Array Isc is most likely to be a limiting factor when the Voc the of PV Array is at the lower end of the operating PV voltage for the controller. Conversely, the closer to the max PV input the PV array operates, the higher wattage the array can typically be without violating the Isc spec of the controller. Consequently, it is usually possible to over-panel a MPPT controller that has an Isc limit by designing the array to produce a Voc that is in the upper end of controller's safe operating range. There are examples of these calculations on the Victron Specific section of this document.

Over-paneling vs larger or additional controller.

It must be acknowledged that when over-paneling, there is unrealized capacity (wasted capacity) of the PV array. This begs the question: Why not use a larger controller or a second controller to harvest the full capability of the array.

The primary reason not to have a larger or additional controller is cost. Controllers can be pricy, and panels are relatively cheap so just adding panels may be the most cost-effective solution. However, there are good reasons to add a controller even if the system does not need the unrealized capacity.

- Having more power production than needed is rarely a problem but having too little is always a problem.
  - Batteries will get charged faster (This is particularly good with Lead Acid batteries)
  - The power will be available for unusual or unexpected surges in need.
- Redundancy: In an off-grid situation it is very beneficial to have multiple controllers in the system. If one controller goes out, the other can still provide the critical power needed.
- Controller Stress: When over-paneled, the controller will be spending more time operating at its max capacity. A quality controller from a reputable manufacturer should be able to handle this…. But it is always best to avoid running equipment at its max capacity.

Notes, Warnings and Limitations.

- I am aware of only one MPPT controller that allows no over-paneling (Sol-Ark 5K). However, be sure to check the limitations of your controller. (You may have to contact the manufacture). Some manufactures specify a maximum array wattage for over-paneling (Typically 30%-50% over-paneling). Others have limits such as Isc that will impact over-paneling. When specified, the limit should be followed. (Since there is a diminishing return on massively over-paneling, the limit may not be a big deal)
- When over-paneled, the controller will be spending more time at its max operating point.
  - Low end controllers that are not designed well may have a higher failure rate.
  - When over-paneling, cooling and ventilation of the controller is more important than ever.
- Since the MPPT controller input voltage is a hard limit, over paneling almost always involves adding panels in parallel.
- Since adding parallel panels to an array will increase the total PV current, the wire size to the array may also need to be increased. When calculating the wire size, the full Isc current (adjusted for temperature) must be used even though the controller may not actually use it.
- When calculating the Voc of the array to determine how many panels can go in series, always adjust for cold weather conditions.
- Any time there are three or more parallel panels or strings of panels, there must be fuses or breakers on each string.
- Always use the same panel make/model throughout an array. If you must use dissimilar panels, the Vmpp and Impp should be as close to the same between panels as possible.
- Over-paneling only applies to MPPT controllers. Do not apply over-paneling to PWM Controllers.
- Some government subsidies or incentives might have limits on over-paneling.
- Related Resources
  Fusing guidelines for solar panels: https://diysolarforum.com/resources/fusing-guidelines-for-solar-panels.143/
  Adjusting Solar Panel Voc for temperature: https://diysolarforum.com/resources/adjusting-solar-panel-voc-for-temperature.219/

A note about 12v Panels and 24V Panels.

When working with an MPPT controller, the concept of 12V panels or 24V panels can be completely ignored. All that is important is the total Voc of the array.

In the past, panels were either hooked directly to the batteries or a PWM controller was used. In these cases, it was important to match the panel voltage to the battery voltage. With so-called 12V panels (actual Voc is ~18V), you could put it on a 12V battery and know the voltage was about right for charging. A 24V panel could be put on a 24 volt battery and the voltage would be about right.

MPPT controllers will transform the input voltage and current to what is needed for battery voltage and current. Consequently, input voltage is almost completely isolated from the output voltage. The only aspect of the battery voltage that impacts the controller input voltage is that the input voltage needs to be some amount higher than the battery voltage for the controller to start up and run. (This is usually ~5V higher than battery voltage to start and 1V-3V higher than battery voltage to run…. Check the specs of your controller for specifics)

MPPT Controller Specifics

Check the manual for your controller for any max array size for over paneling or other limits.

(Click on link to jump to pages with more controller specific information)

The following controllers support over-paneling to varying degrees

- Victron SmartSolar and BlueSolar controllers
- Midnite Classic Controllers
- EPEVER Tracer Controllers
- MPP All-In-One Controllers (I have seen Will do it in videos – I am waiting on info from the vendor)
- Sol-Arc 8K & 12K All-In-One Controller
- Fronius
- Schneider Electric 865-1034 Conext MPPT 100 (or MPPT 80)

According to the manufacturers, the following controllers do not support Over-Paneling.

- Growatt SPF 3000 TL
- Sol-Arc 5K All-In-One Controller

Note: Additional vendor specific pages will be added as time and motivation permits and information becomes available.

Victron BlueSolar and SmartSolar controllers (1 of 2)

As with all other MPPT controllers, the primary not-to-exceed spec for the Victron MPPT controllers is the input voltage. However, they also list a “Max Isc” spec. Victron has clearly stated in their manuals that if the PV is hooked up in reverse polarity and the Isc is over the limit, it can damage the controller. It turns out that there are other instances that are not documented in the manual, where exceeding the Isc might be damaging to the controller. Consequently, the system designer should never exceed the Isc Specification on a Victron MPPT Controller.

It is still possible to over-panel a Victron MPPT controller, but the Isc specification will limit the amount of over-paneling and in some panel configurations, the Isc limit will prevent over-paneling. (See the following page for an example of using Isc in calculating how to over-panel a Victron MPPT controller)

Note: It is unusual but possible to go over the Victron Isc spec with configurations that are not over-paneled. Consequently, it is important to check the array Isc even when not over-paneling the controller. Furthermore, the Victron online MPPT calculator does not appear to check the Isc of a configuration so this must be checked manually even if the calculator indicates the configuration is good.

Victron BlueSolar and SmartSolar controllers (2 of 2)

This example will use the SmartSolar 150/35 MPPT controller and Renogy 100 Watt 12 Volt Monocrystalline Solar Panels.

SmartSolar 150/35 MPPT spec	
Input Voltage Max	150V
Max Output Current	35A
Power on 12V system	490W
Isc Limit	40A

Renogy 100W 12V Solar Panel Spec	
Voc	22.3V
Isc	5.86A
Power	100W

How would we over panel to 800W (8 Panels) on a 12V system?

× 8 panels in parallel would provide an array voltage of 22.3V, leaving ample room for cold weather. However, the array Isc would be 5.86A x 8 = 46.88A which is over the 40A Isc limit of the controller.

× With 8 panels in series the Voc would be 22.3V x 8 = 178.4V…. Exceeding the input voltage limit of the controller.

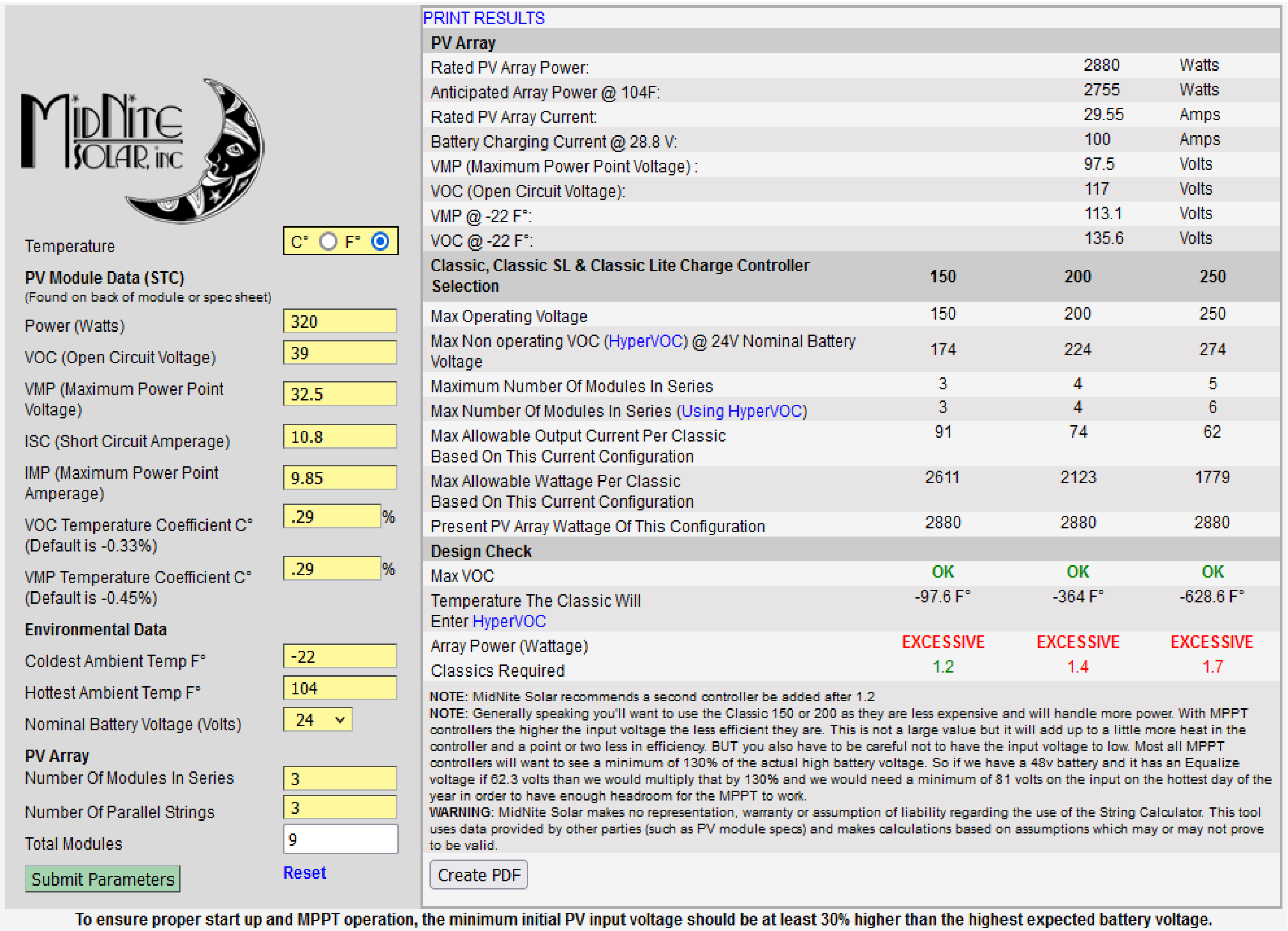
✓ With two parallel strings of 4 panels in series, the Array Voc is 4 x 89.2V. This is within the controller spec and leaves ample room for cold weather voltage rise. The array Isc will be 2 x 5.86 = 11.72a, well under the 40A limit of the controller. <u>This configuration will work and is over-paneled by ~63%.</u>

Notice that even 4 strings of 5 panels (2000W total) would not exceed any of the SmartSolar 150/35 controller specifications. (2000W on a 490W controller would be way past the point of diminishing returns, but it would work)

Midnight Solar Classic

The Midnite Solar Classic manual does not directly address over-paneling, but their phone tech support assures me that the Classic will simply current limit the output if the array can produce more power than the Classic can pump into the batteries. As with all controllers the Voc is a critical specification that must not be exceeded.

The Midnight online calculator (shown to the right) will indicate an additional controller is needed if the over-paneling is over 20%. The calculator assumes that over-paneling by 20% will make up for the difference between the rated STC power and actual, real-world production. Above that it recommends an additional controller in order to capture the extra power. However, the recommendation does not imply a damaging condition when using a single controller.



MIDNITE SOLAR INC

Temperature	C° ○ F° ◉
PV Module Data (STC) (Found on back of module or spec sheet)	
Power (Watts)	320
VOC (Open Circuit Voltage)	39
VMP (Maximum Power Point Voltage)	32.5
ISC (Short Circuit Amperage)	10.8
IMP (Maximum Power Point Amperage)	9.85
VOC Temperature Coefficient C° (Default is -0.33%)	.29 %
VMP Temperature Coefficient C° (Default is -0.45%)	.29 %
Environmental Data	
Coldest Ambient Temp F°	-22
Hottest Ambient Temp F°	104
Nominal Battery Voltage (Volts)	24
PV Array	
Number Of Modules In Series	3
Number Of Parallel Strings	3
Total Modules	9

Submit Parameters Reset

PRINT RESULTS

PV Array		
Rated PV Array Power:	2880	Watts
Anticipated Array Power @ 104F:	2755	Watts
Rated PV Array Current:	29.55	Amps
Battery Charging Current @ 28.8 V:	100	Amps
VMP (Maximum Power Point Voltage) :	97.5	Volts
VOC (Open Circuit Voltage):	117	Volts
VMP @ -22 F°:	113.1	Volts
VOC @ -22 F°:	135.6	Volts

Classic, Classic SL & Classic Lite Charge Controller Selection	**150**	**200**	**250**
Max Operating Voltage	150	200	250
Max Non operating VOC (HyperVOC) @ 24V Nominal Battery Voltage	174	224	274
Maximum Number Of Modules In Series	3	4	5
Max Number Of Modules In Series (Using HyperVOC)	3	4	6
Max Allowable Output Current Per Classic Based On This Current Configuration	91	74	62
Max Allowable Wattage Per Classic Based On This Current Configuration	2611	2123	1779
Present PV Array Wattage Of This Configuration	2880	2880	2880
Design Check			
Max VOC	OK	OK	OK
Temperature The Classic Will Enter HyperVOC	-97.6 F°	-364 F°	-628.6 F°
Array Power (Wattage)	EXCESSIVE	EXCESSIVE	EXCESSIVE
Classics Required	1.2	1.4	1.7

NOTE: MidNite Solar recommends a second controller be added after 1.2
NOTE: Generally speaking you'll want to use the Classic 150 or 200 as they are less expensive and will handle more power. With MPPT controllers the higher the input voltage the less efficient they are. This is not a large value but it will add up to a little more heat in the controller and a point or two less in efficiency. BUT you also have to be careful not to have the input voltage to low. Most all MPPT controllers will want to see a minimum of 130% of the actual high battery voltage. So if we have a 48v battery and it has an Equalize voltage if 62.3 volts than we would multiply that by 130% and we would need a minimum of 81 volts on the input on the hottest day of the year in order to have enough headroom for the MPPT to work.
WARNING: MidNite Solar makes no representation, warranty or assumption of liability regarding the use of the String Calculator. This tool uses data provided by other parties (such as PV module specs) and makes calculations based on assumptions which may or may not prove to be valid.

Create PDF

To ensure proper start up and MPPT operation, the minimum initial PV input voltage should be at least 30% higher than the highest expected battery voltage.

Note: The AimsPower 320W Monocrystalline solar panel was used for the above calculation.

EPever Tracer & DuoRacer controllers

The image to the left is from the EPever Tracer manual.
As can be seen, the Tracer has a simple limit of a 50% over-paneling.

The EPever DuoRacer controller has the same 50% over-paneling limit and a corresponding chart in it's manual.

Condition 4: Actual charging current of the PV array>Rated charging current of the controller

When the controller operates under "Condition 3" or "Condition 4,"， it will carry out the charging as per the rated current or power.

CAUTION	The controller may be damaged when: 1. The PV module's power is greater than the rated charging power. 2. The PV array's maximum open-circuit voltage is more than 60(Tracer**06AN)/100V(Tracer**10AN)(at the lowest environmental temperature).

According to the "Peak Sun Hours diagram," if the PV array's power exceeds the controller's rated charging power, the charging time as per the rated power is prolonged. The controller can obtain more energy. However, in the practical application, the maximum power of the PV array shall be not higher than 1.5 times the rated charging power of the controller. Suppose the maximum power of the PV array exceeds the rated charging power of the controller too much. In that case, it causes the waste of the PV array, and increases the PV array's open-circuit voltage, which may increase the probability of damage to the controller. For the recommended maximum power of the PV array, please refer to the table below:

Model	Rated charge current	Rated charge power	PV array Max. PV power	Max. PV open circuit voltage
Tracer1206AN	10A	130W/12V 260W/24V	195W/12V 390W/24V	46V(At 25℃ operating environment) 60V(lowest environmental temperature)
Tracer2206AN	20A	260W/12V 520W/24V	390W/12V 780W/24V	
Tracer1210AN	10A	130W/12V 260W/24V	195W/12V 390W/24V	92V(At 25℃ operating environment) 100V(lowest environmental temperature)
Tracer2210AN	20A	260W/12V 520W/24V	390W/12V 780W/24V	
Tracer3210AN	30A	390W/12V 780W/24V	580W/12V 1170W/24V	
Tracer4210AN	40A	520W/12V 1040W/24V	780W/12V 1560W/24V	

Sol-Ark 8K and 12K

The image to the left is from the SolArk 12K manual.
This implies the SolArk is limited to 8.3% over-paneling.

The SolArk 8K has a similar spec sheet and indicates a max over-panel of 37.5%

The low limits on the 12K and 8K are surprising for a known brand like Sol-Arc, but their Tech support has confirmed the limitation.

Solar	Input Power 12000W
Max Allowed PV Power	6500W + 6500W = 13000W
Max PV Power Delivered to Battery & AC Outputs	12000W
Max DC Voltage (Voc)	500V @ 18A, 450V @ 20A
MPPT Voltage Range	150-425V
Starting Voltage	125V
Number of MPPT	2
Max Solar Strings Per MPPT	2
Max DC Current per MPPT (Self Limiting)	20A
Max AC Coupled Input (Micro/String Inverters)	9600W

Sol-Ark 5K

No over-paneling supported

The image to the left is from the SolArk 5K manual. The 3250W per controller is a hard limit.

This is surprising for a known brand like Sol-Arc, but their Tech support has confirmed the limitation.

Sol-Ark-5K-48-ST Specifications	
Solar Output Power 6500W	
Max allowed PV Power	3250W+3250W = 6,500W
Max PV power delivered to Battery & AC outputs	6500W
Max DC voltage	500V
MPPT voltage range	150-425V
Starting voltage	125V
Number of MPPT	2
Max Solar Strings per MPPT	2
Max DC current per MPPT (self limiting)	10A/10A

Schneider Electric Conext MPPT 100 (or MPPT 80)

The image to the left is from the Schneider Electric Conext manual.

	MPPT 80 600	MPPT 100 600
Electrical Specifications		
Max PV array open circuit voltage	600 V	600 V
MPPT voltage range	195 to 510 VDC	195 to 510 VDC
PV array operating voltage	195 to 550 V	195 to 550 V
Max. array short circuit current at STC	28 A	35 A
Max. input operating current	23 A	29 A
Max. output power	4800 W (nominal 48 V systems)	6000 W (nominal 48 V systems)
Nominal battery voltage	24 and 48 VDC	24 and 48 VDC
Battery voltage operating range	16 to 67 VDC	16 to 67 VDC
Max. output charge current	80 A	100 A
Charger regulation method	Three-stage (bulk, absorption, float) plus manual equalization Two-stage (bulk, absorption) plus manual equalization	
Supported battery types	Flooded, GEL, AGM, Lithium-ion, Custom	

It appears the limiting factor for over-paneling these controllers is the ‘Max. array short circuit current at STC’. The over paneling can be quite high without exceeding the controller specification, but the system designer will find that to keep the array Isc below the limit, the Array Voc will typically be in the higher part of the allowable range. (This is typical for controllers with an Isc limit in the specifications)

Growatt SPF 3000 TL

The image below is from the Growatt SPF300TL data sheet.   Growatt tech support says the Max PV Array Power is a hard limit, so these controllers can not be over-paneled.

Datasheet	SPF 3000TL HVM-24	SPF 3000TL HVM-48	SPF 5000TL HVM/HVM-P
SOLAR CHARGER			
Maximum PV Array Power	1500W	1800W	4500W
MPPT Range @ Operating Voltage	30VDC ~ 80VDC	60VDC ~ 115VDC	60VDC ~115VDC
Maximum PV Array Open Circuit Voltage	102VDC	145VDC	145VDC
Maximum Solar Charge Current	50A	30A	80A
Maximum Efficiency	98%	98%	98%