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An introduction to

# Boat Solar Systems

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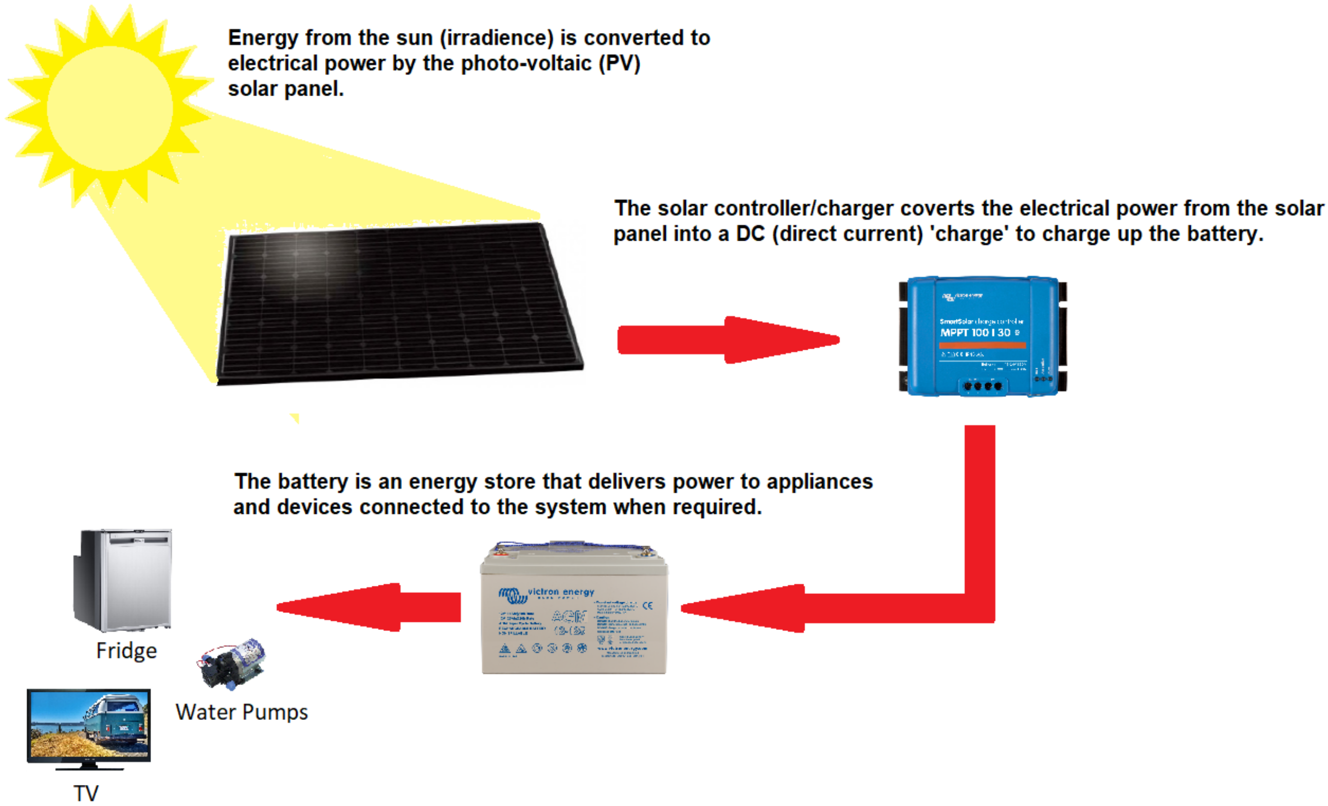
The first thing to remember when selecting a solar PV solution for your boat is what it's actually for! A solar PV system is simply a method to re-charge the batteries. For boat installations, a solar PV system is not a power source to run appliances directly, it is a battery charger used to replace the energy consumed from the batteries, which in turn are powering the appliances.

To clarify, let's look at how a power delivery and energy storage system actually works on a boat.




So, a complete system requires a solar panel or panels, a controller/charger, battery and the various fuses, cable and connectors to hook it all together.

When sizing a solar system for your boat, there are a number of things to take into consideration including:

1. What type of service batteries do you have or intend to have and what is the overall capacity?
3. How much energy are you consuming and what is the ideal charge rate for your batteries?
4. How much clear roof space do you have for the solar panel/s including mounting?
5. What is your overall budget?

**Batteries and charging:**

The most popular types of batteries installed on boats are either Lead-Acid - Sealed Lead-Acid (SLA) 'Leisure' batteries or Absorbed Glass Mat (AGM) batteries or LiFePO4 "Lithium" batteries which are becoming more popular as their cost reduces and the benefits become more apparent. You should already be aware of your battery capacity and how much energy you're consuming day-to-day so you should have a rough idea of the charging requirement. Generally, you would specify a battery charger capable of delivering a charge equivalent to around 20% of your battery capacity plus any continuous load for example; if you have a 400Ah 'Leisure' battery bank and the fridge is on all the time drawing 2A, a charger of 82A would be a decent compromise between the time taken to re-charge and service life of the battery.

A solar system capable of delivering an 80A charge would probably be a tight squeeze to fit on a narrowboat but possible on a widebeam so a compromise must be made. A smaller charger will do the job but take longer to charge the batteries unless you have 'Lithium' of course!

When specifying solar PV systems for boats, the space available to mount suitable panels can be the most limiting factor. Therefore, it's necessary to ensure the maximum yield available from the panels is achieved, under varying conditions, in order to deliver a decent charge to the batteries.

This is where your choice of solar controller/charger is critical. There are essentially two types of solar controller/charger – PWM and MPPT.

**The Solar Controller/Charger:**


*PWM Regulator*

A PWM regulator is in essence an inexpensive switch that connects solar panels to the battery. The PWM regulates the voltage from the panels down to the battery charging voltage. For smaller panels (less than 19V) this is OK but for larger panels, where the panel output could be typically 35V or more, all that additional energy is wasted. A PWM used in that example could see 35% of the available energy lost as it pulls the voltage down to the battery charge voltage!


*MPPT Controller/Charger*

A true MPPT controller is much more sophisticated. It will adjust its input voltage to harvest the maximum possible power from the solar panels and then transform this power to supply the varying voltage requirement of the battery (charging plus load). It essentially decouples the solar panel and battery voltages so that there can be, for example, a 12V battery on one side of the MPPT and solar panels generating 30-40V or more on the other. This ability to harvest the maximum power and the efficiency of the system means that you can use inexpensive commercial panels, taking up less space on the roof, to generate a much higher charge to the battery.

**Not all controller/chargers are created equal!**

A true MPPT controller/charger uses hardware and sophisticated software to control the system and optimise the battery charging. Within the software there are algorithms that execute the calculations. There are about 19 different algorithms used commercially in MPPT controller/chargers – some are very basic (cheap to implement!)

and some extremely complex (expensive to implement!) - one of the reasons why there is quite a variance in cost when you look at MPPT controller/chargers.

There are also many fake MPPT controllers out there – simply re-badged, cheap PWM regulators sold on shopping websites. Expect to pay around £100 or more (depending on size) for a real MPPT. If you see one advertised on-line for £15, odds are it's a fake!

**Maximum Power Point Tracking (MPPT):**

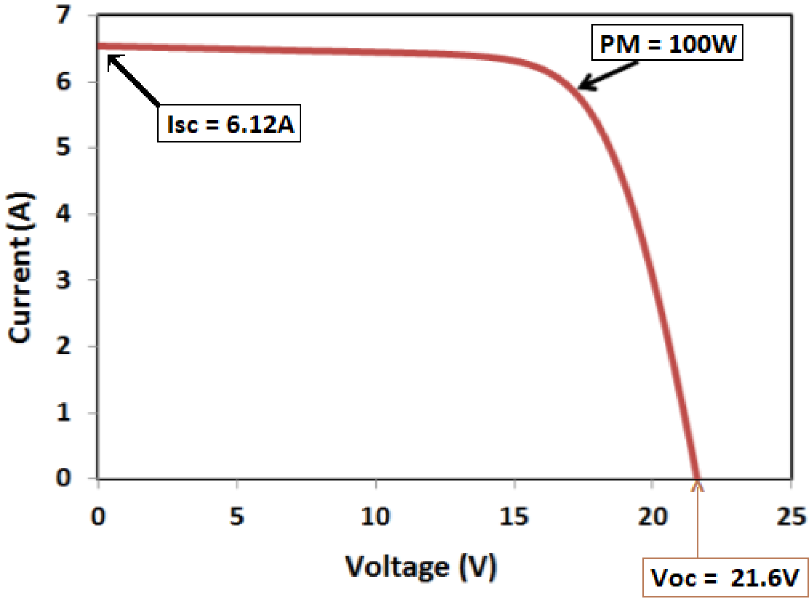
Solar panels produce power (Watts) calculated from the voltage x current. If you map these outputs, you can produce a current-voltage curve and a power-voltage curve. Maximum Power is generated at the optimum point on the power-voltage curve, hence the term Maximum Power Point (MPP). As conditions change (shading, light pollution etc.) the current-voltage curve and power-voltage curve change so a panel can produce numerous current-voltage curves and power-voltage curves throughout the day.

**The current-voltage curve and the power-voltage curve of a solar panel:**

The following example is based on a typical 100W monocrystalline solar panel with the following specification:

| | |
|---|---|
| Power Maximum (Pm) | 100W |
| Voltage at maximum power (Vmp) | 18V |
| Current at maximum power (Imp) | 5.56A |
| Open circuit voltage (Voc) | 21.6V |
| Short circuit current (Isc) | 6.12A |
| Temp. coefficient of Voc (β) | -0.35 %/°C |
| Temp. coefficient of Isc (α) | 0.05 %/°C |

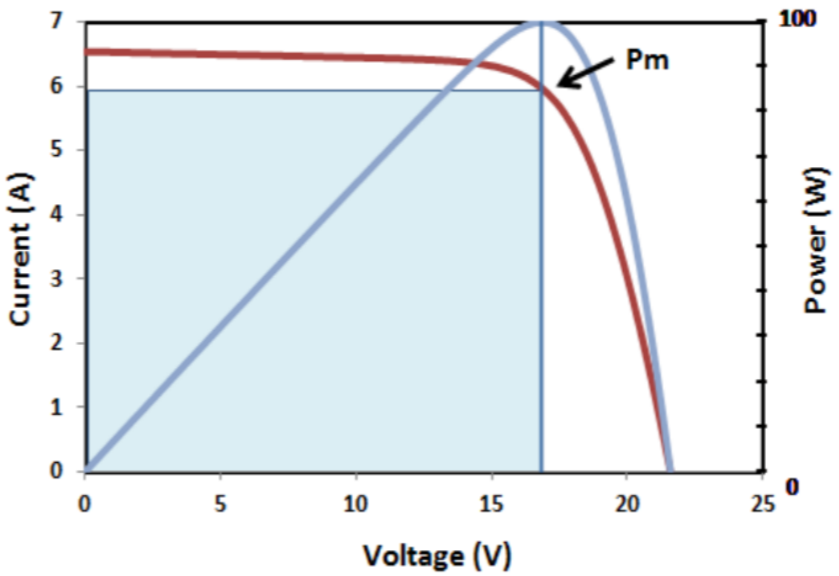
The **current-voltage curve** of this panel at Standard Test Conditions (STC)* is



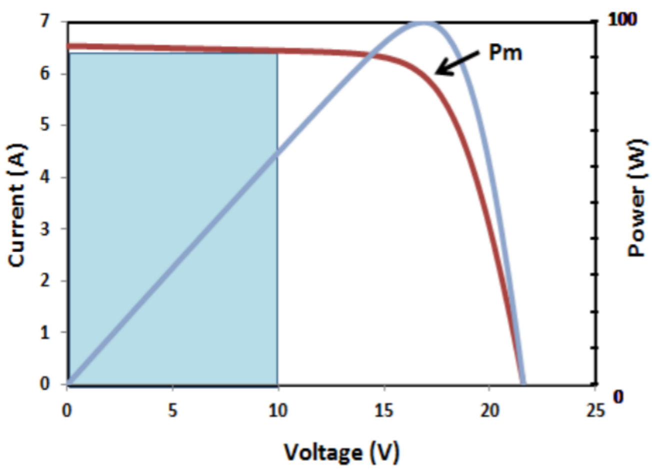

*Standard Test Conditions (STC)* are the industry standard for the conditions under which a solar panel is tested. By using a fixed set of conditions, all solar panels can be more accurately compared and rated against each other. The test conditions are defined as follows - irradiation: 1000 W/m², temperature: 25°C, AM: 1,5 (AM stands for Air Mass, the thickness of the atmosphere; at the equator, air mass = 1, in Europe approx. 1,5).

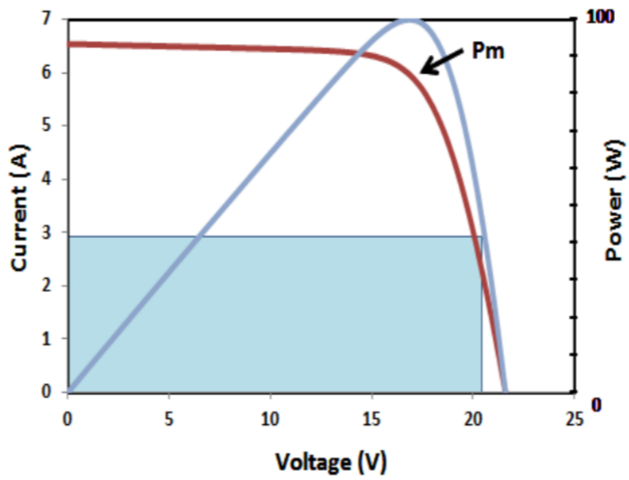
From this basic current-voltage curve the **power-voltage curve** can be derived by plotting P = V x I against V.

The result is the blue curve below.




The product Vm x Im is proportional to the area of the rectangle (above). Maximum Power (Pm) is reached when the area of this rectangle is at its largest.



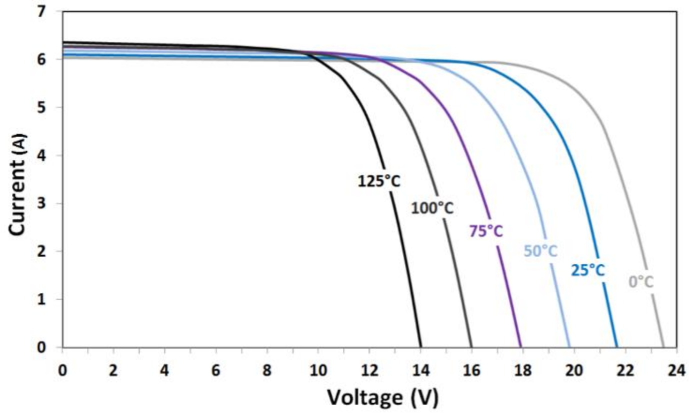




If the voltage is too low (above-left) less power is harvested from the panel. If the voltage is too high (above-right) less power is harvested.

The power obtained from the panel is zero when it is short circuited (0 x Isc = 0) or when no current is drawn from the panel (Voc x 0 = 0). In between those two zero power points the product P = V x I reaches a maximum: the **Maximum Power Point** (Pm = Vm x Im).

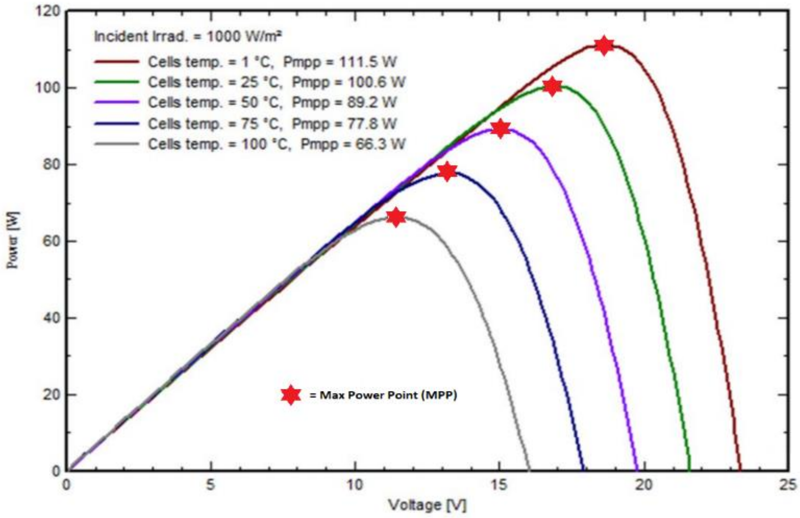
**Temperature:**

The temperature of the cells within a solar panel has a significant effect on the panel performance. When a panel heats up, both the open circuit voltage (Voc) and the Maximum Power Point voltage become lower. The current remains fairly constant so the current-voltage curve moves to the left as the cell temperature increases.




As the cell temperature increases, the voltage produced by the panel decreases. Conversely, as the cell temperature reduces, the voltage increases.

This is why it is important to take temperature into account when calculating the size of controller/charger required for a system. A panel rated at say, 20V is capable of producing a much higher voltage (in this example c.24V @ 0˚C).




As the voltage changes, the Maximum Power Point (Mpp) moves. The MPPT controller/charger needs to track these changes in order to maintain the optimum charge to the battery.

The speed at which the MPPT controller/charger tracks these changes and locates the optimum power point, has a direct bearing on the overall performance of your system.

In order to get the maximum out of a solar panel, a controller/charger should be able to locate the optimum current-voltage point on the current-voltage curve - the Maximum Power Point. As conditions change, the voltage of the panel changes and hence the position of the Maximum Power Point changes.

The controller/charger needs to track the Maximum Power Point as it changes, in order to maintain the maximum power it can convert to battery charging – hence the term **Maximum Power Point Tracking (MPPT)**. The speed at which the controller/charger tracks not only the Maximum Power Point but also the current-voltage curve producing it, has a direct affect on the efficiency of the system and ultimately the charging of the battery.

When the sky is cloudy, when there may be shadows, light intensity is changing continuously. A fast MPPT algorithm will improve energy harvest by up to 30% compared to PWM charge controllers and by up to 10% compared to slower MPPT controllers. From a user perspective, this means that a quality MPPT, with sophisticated software/algorithms will start charging your battery earlier in the day and will generate a higher/better charge to your batteries for a longer period than a more basic offering.

**What size system?**

A solar system should be designed to suit your own particular requirements. These will differ depending on whether or not you live aboard, the space you have available for panels, the size of your battery bank/energy consumption and your overall budget. If you use your boat for weekends/holidays then a modest system with a decent MPPT controller/charger will do the job – it has most of the week to charge your batteries up. If you live aboard, then you need a system that will cope as far as possible with the daily discharge/charge of your batteries.

Beware of on-line calculators! There are lots of “Solar Calculators” on-line, the vast majority of which do not take into consideration important factors like temperature, local conditions, realistic panel outputs etc and as a result are usually miles out! Your supplier should be able to run the calculations to size a system properly to suit your requirements and our UK weather.

**A note about Rigid or Semi-Flexible Solar Panels**

Solar panels used on boats are either rigid framed or semi-flexible. Rigid framed panels produce more power for a given surface area, are less expensive but require mountings, can't be walked on and, some would argue, don't look as nice as semi-flexible panels. So, if aesthetics is a priority, and/or you need to be able to walk on them, then semi-flexible panels would seem to be the preference. However, they have some major limitations. They tend to be made with an aluminium insert so when bonded to a steel roof, are subjected to different rates of expansion/contraction to the roof, as the roof heats up and cools during the day. This can cause a semi-flexible panel to degrade over time and it's not unusual for them to fail after a few years – one of the reasons they rarely come with more than a year or two's warranty. Whereas rigid framed panels will last decades and it's not unusual to see 10-25 year warranties on rigid panels.

**To summarise:**

1. A solar PV system is in effect just a battery charger so when sizing a system think in those terms and ask your supplier to produce the calculations.
2. Get the best quality MPPT controller you can and check the specifications carefully – beware of fake/cheap units.
3. For a metal boat, go for rigid panels if you can or if they must be semi-flexible, check the specifications, quality and warranty.

A properly specified solar system will give you years of reliable charging saving on engine/generator run-time, maintenance and cost. Not only that but with zero-emissions, you're doing your bit for the environment too!

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