MPPT vs PWM Test | What Is The Difference Between MPPT and PWM?

It's often one of the first questions asked by people getting into solar systems. There are two main categories of solar charge controller, so **which one is better, PWM or MPPT**? A simple question which doesn't always give an easy answer.

What is the difference between PWM and MPPT charge controllers?

The difference between MPPT and PWM controllers is that the PWM controller pulls the solar panel voltage down to just above battery voltage, away from the Maximum Power Point (MPP) of the panel. An MPPT controller matches its internal resistance to the solar panel Characteristic Resistance, drawing current at the Maximum Power Point.

As usual, I decided to find out for myself and set up a little **experiment** using an example of each controller in the **same insolation** levels, measuring the panel **output in watts** as each panel charge an identical battery.

Below my own experiment I added a video with transcript of a pretty good explanation of how each type works, but before I carry on, here's the results of my findings.

MPPT controllers take advantage of the maximum power point of the solar panel. At this point the voltage and current are maximum and so is the power output in watts, as V x I = Watts.

In tests, the MPPT controller transferred **20% to 25% more power** to charge a battery than the PWM controller in identical conditions.

Let's go with the details of the test.

MPPT vs PWM Test by Author

Equipment used:

- **100 watt flexible** monocrystalline solar panel (unbranded)
- cheap bottom-of-the-range **20 amp PWM** solar charge controller (unbranded)
- mid-range **350 watt MPPT** (30 amp@12 volt) solar charge controller (MPPT5025A-DUO-BT)
- DC wattmeter
- 30Ah lithium phosphate battery (used as load)

20A PWM Solar Charge Controller

30A MPPT Solar Charge Controller

MPPT vs PWM Test Procedure:

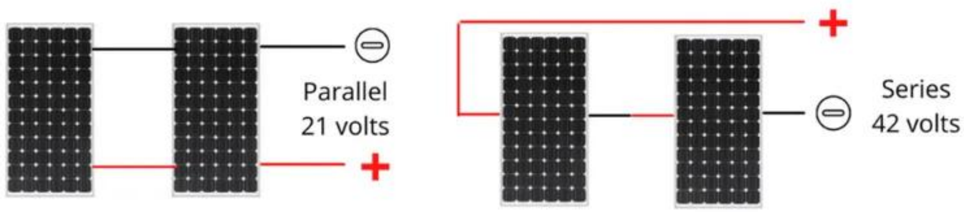
After extensive research across the internet it seems that the common view that MPPT controllers are up to **30% more efficient** than PWM is not strictly true in all situations.

Many professionals maintain that for small arrays in warm climates the **difference is negligible** and that **MPPT** only truly comes into it's own when several panels are connected **in series**, thereby raising the PV input volts above the battery terminal volts.

The other problem is making sure that **test conditions** between controllers/panels are **identical,** particularly in low power systems of under 200 watts. Nevertheless, I'll go ahead and see what results I get.

I'm using a partially discharged lithium **battery** as a load. To make sure I don't fall into the trap of using two batteries that are not identical, I'll test both controllers with the same panels (**2 x 100 watts**) and the same battery for **2 hours each at mid-day** in exactly the same solar conditions. I won't bother measuring irradiance as it's a **comparison test**.

The panels will be connected in **parallel** for the PWM test (PV input volts = **21 volts**) and in **series** for the **MPPT test** (**42 volts**) – I've read the MPPT performs better when the PV input volts is significantly higher than battery terminal voltage.



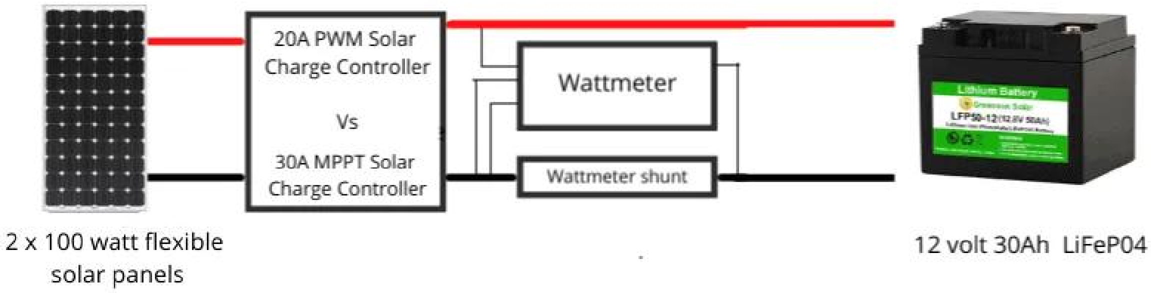
How do I test my MPPT charge controller?

In each case, the panels were tilted at the same angle **perpendicular to the sun** on a bright day.

Panel rating in total is **200 watts** but as the test was carried out in February in Portugal, I expect the output power to be about **33% of full capacity** (irradiance here in February averages **350kW/m2**).

See the wiring setup below – it's very simple. I hook up the battery to the PWM controller, connect the solar panels and let them charge the battery for an hour or two.

I'll then change over to the MPPT charge controller and carry out the same test, ensuring that the sky is clear.



Real-world MPPT vs PWM testing

Table – MPPT vs PWM Test – Results

Solar Panel Configeration	Input Voltage	PWM Power Transferred	MPPTPower Transferred	MPPT % Gain
2 x 100 Parallel	21 volts	58		22%
2 x 100 Series	42 volts		73	

However, it has to be said that the test results are particular to this experiment and can't really be said to be representative of all situations – there are simply too many variables.

The following table gathers several **actual test results** from various locations, in various weather conditions with different solar panel power ratings:

Panel Ratings	**Location**	Weather/Temp	**PWM Power (Watts)**	**MPPT Power (Watts)**	% Gain for MPPT
1400 watts	US Pacific N-W	Overcast - 5 degrees C - very low light	315	412	+24%
50 watts	Phillipines	Cloudy morning - 26	17	22.5	+24.5%

		degrees C			
100 watts	Mass, USA	Sunny	37	67	+45%
140 watts	Maine, USA	Cloudy, mixed, rain	182	220	+21%
100 watts		Sunny, bright	78	97	+20%
200 watts	Indiana	Sunny, bright	125	160	+22%

MPPT vs PWM test – which is better?

Test results are fairly conclusive and most show that the MPPT controller does give between 20 to 25% gains in a variety of conditions. One outlier even shows a gain of 45% but it would be prudent to go with the majority and state that the MPPT is a solid 30% more efficient than the PWM.

This is one of the great benefits of gathering numerous test results – the average values give us some confidence in what we can expect from an MPPT controller.

Why is MPPT Better Than PWM?

People connect solar panels directly to the load without understanding what they're doing – this is very inefficient.

When you do that, much of the power generated by your panel is lost. When a solar panel has peak power output it also generates its own **internal resistance** which varies with its output level. This is called the panel's **'characteristic resistance'.**

An MPPT controller matches its internal resistance to the solar panel Characteristic Resistance, drawing power at the Maximum Power Point. A PWM controller pulls the solar panel voltage down to just above battery voltage, away from the Maximum Power Point of the panel. MPPT is up to 30% more efficient.

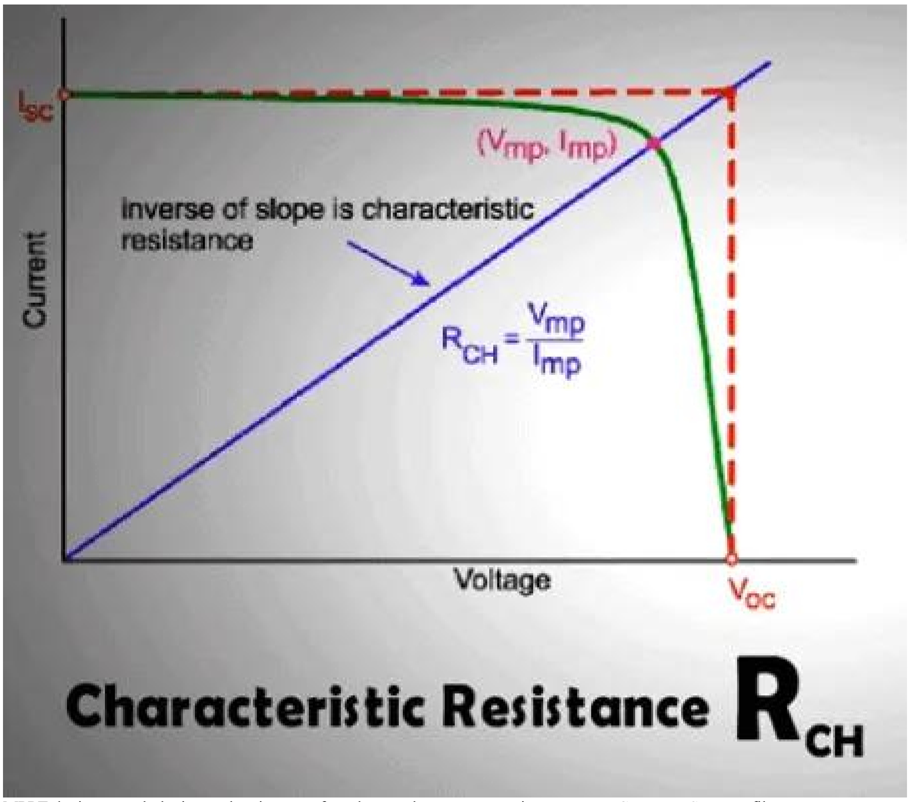
This means if we don't take into account this resistance in our design then a large proportion of all energy from sunlight hitting that photovoltaic cell **will get wasted**!

When a solar panel is connected to a load, the closer that **load's internal resistance matches** with the **characteristic resistance** of the panel, then more power can be extracted from it.

In reality, output isn't just dependent on how much light is received, but also depends upon what type of resistor or "**load**" has been connected to it.

To match the resistances is difficult because normally you may have a solar panel which has a characteristic resistance of **3 to 5 ohms** and you are trying to connect it with an internal battery that could be **less than 1 ohm**.

You can roughly figure out this value by dividing the maximum power voltage (**V MP**) from your solar panel with its current (**I YMP**). This information should be on the specification sheet for your particular model of solar panel.



MPPT devices match the internal resistance of a solar panel to extract maximum power. Courtesy: Synergy files

If we have a specification sheet with a maximum power voltage and maximum power current, we can use them to determine the panel's characteristic resistance. Let's say it's **3.43 ohms.**

If the maximum current, and voltage can't be found, the value for the characteristic resistance is then obtained by using **closed circuit current (Isc) and open circuit voltage(Voc)** values – this is a good enough estimate.

With a **load resistance** around 3.43 ohms, this solar panel will deliver the **maximum amount of power** it can.

If the panel is rated at 280 watts and if we don't match the resistances, then we **won't be able to draw** anywhere near that load.

What's the solution for finding a load with **similar internal resistance** value to your solar panels?

An **MPPT** device serves as a **kind of buffer** between your panel and your load, making it much more efficient. MPPT is a better term for Maximum Power Point Tracking.

MPPT (maximum power point tracking) is an innovative technology that **maximizes the power** generated by your solar inverter.

The video below does a good job of explaining how the two controllers work in practical terms with graphs to illustrate principles that are sometimes not too clear:

PWM Vs MPPT – Are MPPT controllers worth it?

Video – PWM vs MPPT – What's Best and Why?

I'm going to be talking about **solar regulators** or solar **controllers**, in particular the two most common types **PWM** and **MPPT**. In this video I'm going to be going through how they work, their differences and why one might be better than the other for your setup.

Now a **12 volt solar panel** is generally putting out somewhere between 18 to 20 volts**,** which is why it's so important that you need a regulator.

If you simply plugged your solar blanket or solar panel into your battery it would work at first but then as the charging voltage climbs it'll **eventually cook your battery**. That's no good!

Back in the day there wasn't much choice. When it came to solar regulators or solar controllers you basically had an **on off switch,** so that when the sun was out and your battery was discharged, the switch would be on and it would charge up your battery.

Once your battery hit that high voltage point where it didn't need any more, you'd have to turn it off or it would turn off to stop cooking the battery.

Now that wasn't particularly efficient and it didn't charge the battery properly. These days though you've got much better options so let's see what you need for your setup.

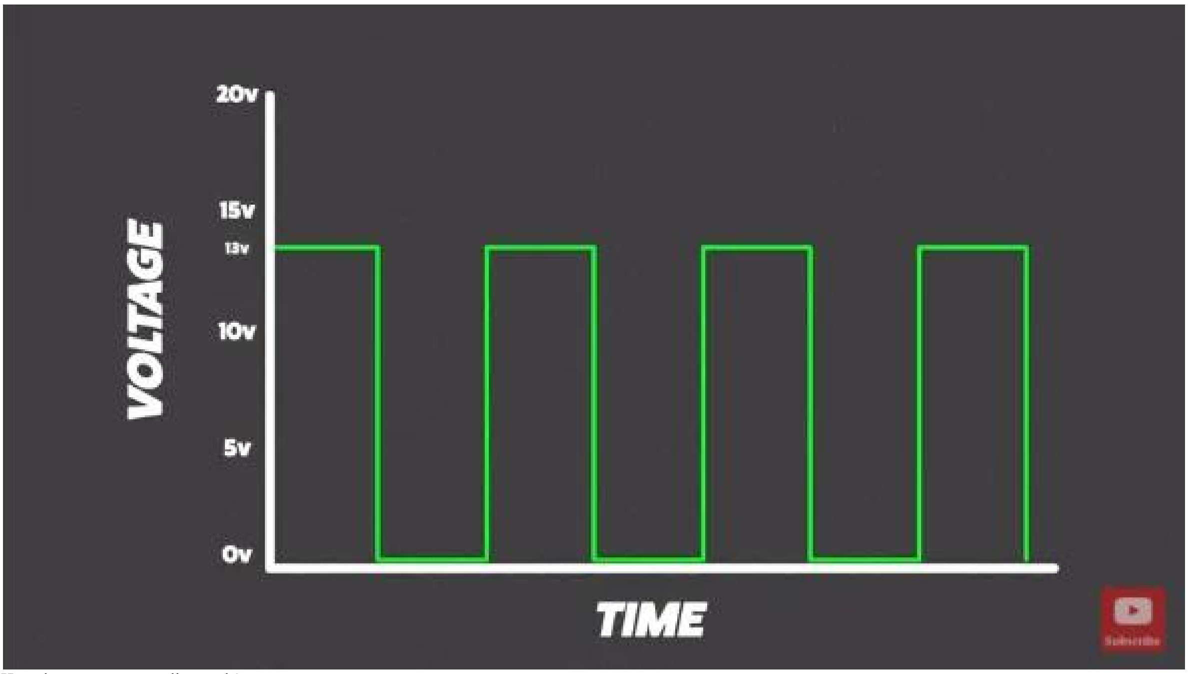
To start with let's talk about **PWM**, which stands for **Pulse Width Modulation** and that's describing what this unit's doing when it's charging your battery.

PWM solar charge controller working principle

To start with it **pulses power** into the battery and it can actually change the amount of time or width of that charge, so it's actually modulating the length of the pulse. That might sound fairly technical, so let's take a look at a graph to make it easier to understand.

On the vertical axis of the graph it's showing your **voltage** and on the horizontal axis is the **time**. As you can see when the regulator turns on it's at voltage then turns off for a short period of time before it turns on again.

Every time the regulator turns off it **measures the voltage** of the battery and **adjusts for the next pulse**.



How does a pwm controller work?

You might have noticed that on this graph the charging voltage is **13 volts**. That's because when you connect a PWM regulator to a solar panel and battery, the large load of the battery actually pulls the solar panel voltage down to just above the battery voltage.

They're not able to actually boost that voltage any higher. The voltage will simply **increase** as the **battery charges up.**

Then the regulator will output the higher voltage but shorten the width of each pulse. Now let's talk about that in the real world. so let's use this 200 watt solar blanket as an example.

Now I do have the exact specs but to make it easier let's assume it's putting out 20 volts and 10 amps. **20 volts times 10 amps is 200 watts.**

Once you connect this to your PWM regulator the battery will pull that voltage down to around 13 volts and because it’s not actually able to boost the output power, you’re now at **13 volts times 10 amps** for a total of **130 watts**. So your 200 watt solar blanket is only able to put out 130 watts.

As your battery is charging up, that internal voltage does climb. Let’s say it gets right up to **14.5 volts**. If you’re still getting **10 amps**, you’re now at **145 watts** but unfortunately you’re never going to get the full 200 watts out of a PWM regulator.

So why would you want a PWM regulator? Well there’s a list of pros and cons that might help you out.

- One massive advantage is their cost. **PWM** regulators are fairly **inexpensive** ,which means you can get into a solar setup without a massive entry cost.
- Secondly, they’re tested technology and they’re arguably more reliable and durable because they have much less complex technology inside. Now the cons.

PWM solar charge controller settings – Cons

For a **PWM** regulator number one disadvantage is that because they only charge at battery voltage or just above it they’re only around **70 percent efficient.**

They can’t boost the voltage or amperage that’s coming out of the unit. They **can’t use 24 volt** solar panels so you can’t take advantage of a higher voltage for less voltage drop in your system.

These can only run with what’s called a **12 volt solar panel**, putting out around **18 to 20 volts**.

Finally they’re not that ideal for a larger solar system, which doesn’t matter too much if you’re only talking about camping or fall driving but you have to be mindful of it if you do ever want to grow your solar array.

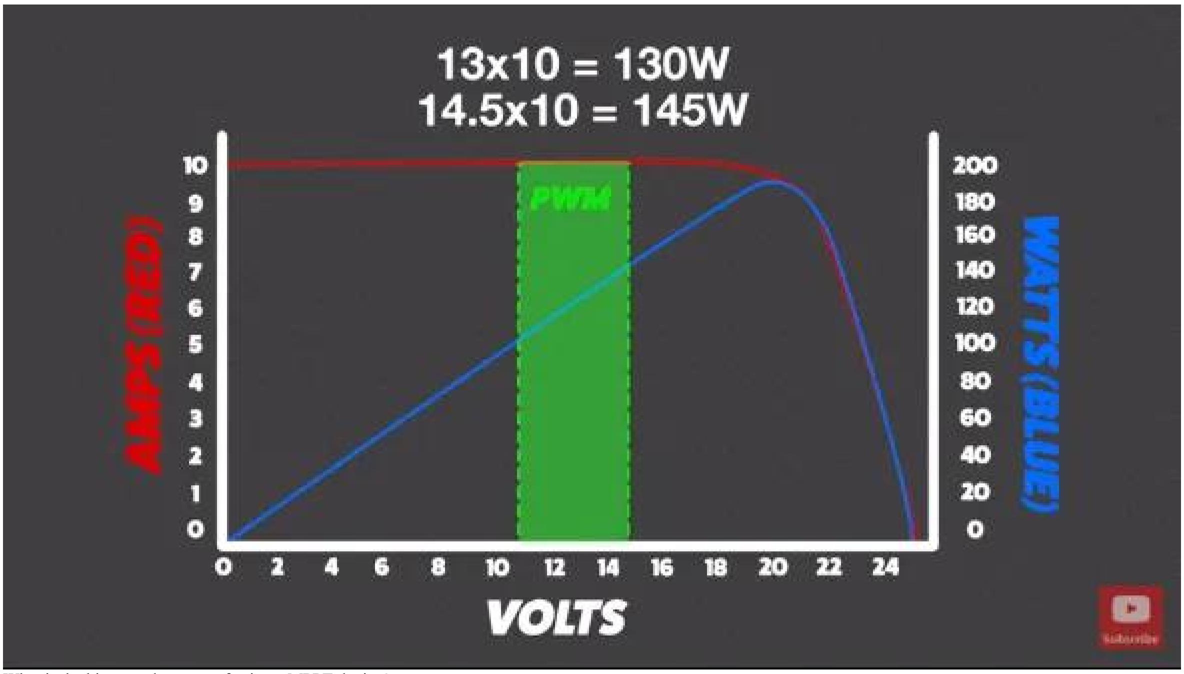
MPPT solar charge principle of operation

Let’s get onto **MPPT** regulators next. Now MPPT stands for **Maximum Power Point Tracking** but that’s not all it does.

The first difference between an MPPT and a PWM is where the PWM simply connects the circuit and brings your solar panel output right down to your battery voltage.

MPPT is **two separate circuits**, so whatever’s coming in is able to go through a computer and then be outputted at a different level.

This is a more technically advanced system which means it's going to charge your batteries much better. Now let's use the same example as before, with a 200 watt panel and take a look at a graph of an MPPT regulator.



What is the biggest advantage of using a MPPT device?

Hypothetically, let's say we've got **200 watts** that's going into the input side of your MPPT regulator or controller.

If your battery needs 13 volts to charge, the MPPT will take that 200 watts divided by the 13 volt output that's required and then output the same amount of power minus a tiny inefficiency.

It'll put out **13 volts** but at around **15 amps**, so actually taking advantage of the entire amount of power that's coming out of your solar panel.

An MPPT has another advantage as well and that is in the name Maximum Power Point Tracking. As an example let's say that the maximum power point of this solar panel sits around here on this graph.

As a cloud passes over it's going to drop the output considerably but the MPPT regulator is able to constantly track it, scanning for that Maximum Power Point and output it. a PWM regulator can't do that.

It's simply a passive system and what this means is that as the solar panel heats up or loses efficiency, clouds pass over or you might have a tiny bit of partial shade on your panel, the **MPPT** is always able to make the most of it and output the **maximum power.**

Do you need a MPPT or MWM solar charger?

Let’s talk the pros and cons of an **MPPT regulator** and why you might want one.

- Well first of all they’re much **more efficient** than a PWM regulator.

- Secondly they’re more able to **use the entire output** of your solar panel because they’re not just passively dropping the voltage to your battery voltage and then using as much current as they can. These are able to actually boost up that current to use the entire panel output.

- Thirdly, because they can track that Maximum Power Point even in low light cloudy conditions, or as the panel heats up, they’re able to **put out more power more efficiently** than a PWM.

- Lastly, because they’re able to actually input a larger voltage you’re **not restricted to using 12 volt** nominal solar panels. You could use a higher voltage solar panel for less voltage drop in your system, which equals more power getting into your batteries.

Now the cons of an MPPT regulator. Number one they’re generally a bit **bigger and heavier** than a PWM of the same capacity but it’s not usually a big deal. Number two, because they’re more advanced inside they’re generally **more expensive.**

MPPT vs PWM test

It’s all well and good to talk about the differences of these regulators on the bench but what’s much more important is to see their actual real load performance.

Let’s take them outside and compare them. Both batteries are discharged to around **12.7 volts or about 75% capacity** and they’ve been sitting overnight.

We’re using the same solar blanket, both laying flat on the ground which isn’t ideal but it’s a good comparison.

What is the difference between PWM and MPPT – what tests show.

Connecting both panels up, the PWM instantly connects the circuit while the MPPT calculates that maximum power point.

After about **30 minutes in the sun** you can see that the battery voltage is already climbing. The panels are heating up. There's voltage drop in the system and it's not a perfectly bright day so we're not at full power.

The **PWM** is putting in around **3 amps or 40 watts of charge**, while the MPPT is taking advantage of the extra power and charging it over **7 amps or just over 100 watts.**

So in summary the MPPT is putting out more than **double the power** of the PWM. The losses in the system, the fact that it's not a perfectly bright day and the heat of the panels mean that we're not getting a full 200 watts but you can see that in the real world that's where the MPPT makes such a massive difference.

So if you want a simple inexpensive option that's going to work in most situations then you can't go past a PWM. However, if you want to make the most of the entire amount of power that your panel's able to put out and ensure that your battery is getting the highest charge it can, you'll need to **step up to an MPPT.**

This is a fairly shallow look at what is a very in-depth topic, so if you do have any questions make sure you throw them in the comments below. If you enjoyed this video make sure you hit 'like' and remember to hit 'subscribe'.

Related Questions

Are MPPT controllers worth it?

In general MPPT solar charge controllers are well worth the extra expense over PWM type. You can expect to gain 30% more power from your solar panel array, a great advantage in intermittently cloudy weather.

Which solar charge controller is best?

MPPT solar charge controllers are best because they extract more power from any given solar panel array. PWM are very cheap but not as efficient. The best known brands of MPPT controller are Victron and Epever.

How does a PWM solar charge controller work?

A PWM solar charge controller samples the battery voltage and regulates the solar panels voltage output to suit the state of discharge of the battery. The controller adjusts the voltage by splitting it up into pulses and varying the time between those pulses. In this way the average voltage changes accordingly.

What is the difference between PWM and MPPT controller?

The main difference between PWM and MPPT controllers is the way in which they handle current and voltage.

Solar panels generate maximum power at a certain voltage when the current is optimal. The internal resistance at this point is called the panel's Characteriostic Resistance.

When the load resistance equals a solar panels Characteristic Resistance maximum power is produced. Typically, battery internal resistance does not match the typical solar panels resistance, so less than maximum power is generated.

A PWM controller pulls the panel voltage down to whatever is required to charge the battery, while a MPPT controller matches it's resistance to that of the panel, basically converting extra voltage into current for charging.

What are the advantages of MPPT?

The big advantage of MPPT is to produce up to 30% more charging current from the same solar panel.

Another advantage is that they are more efficient in cloudy conditions and will extract as much power as possible from the solar panel array in varying weather conditions.

What is the best charge controller for solar panels?

There are many great brands for charge controllers for solar panels, such as Renogy and Victron.

Which brand is used, always go for a well-reviewed, good quality MPPT (Maximum Power Point Tracking) controller for maximum power output.

Source: https://diysolarshack.com/what-is-the-difference-between-mppt-and-pwm-mppt-vs-pwm-test/#mpptvspwm-featuredsnippet