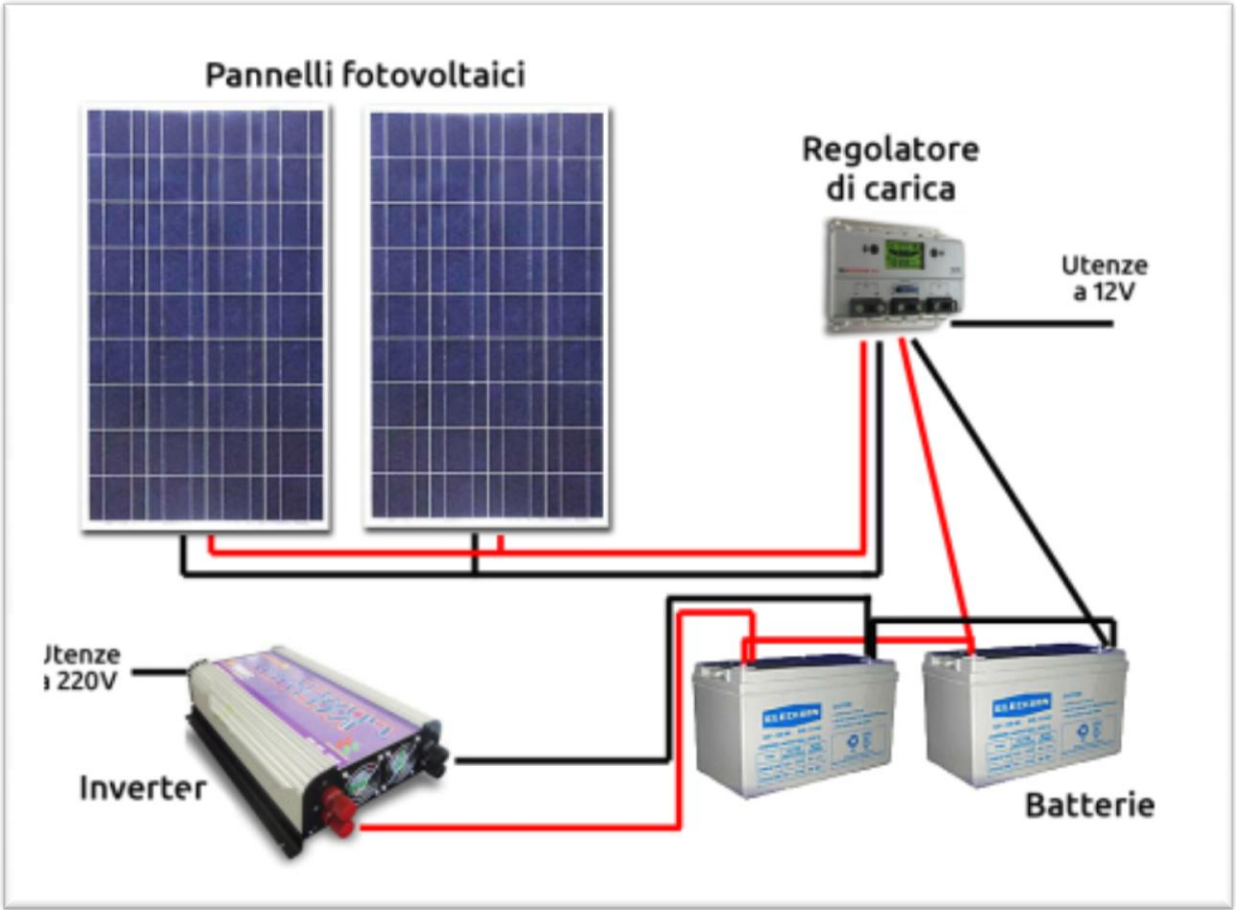
Regolatore di carica solare (mppt o pwm)



Il regolatore di carica è un componente indispensabile per caricare le batterie di un impianto fotovoltaico “stand alone”. Esso riduce la tensione fornita dal pannello (che generalmente supera di molto quella della batteria es. 12v) ad un valore compatibile con quello di carica delle batterie (12 o 24 volt).

Che cos'è un regolatore di carica solare PWM?

PWM (è l’acronimo di: Pulse Width Modulation)

Questi regolatori di carica sono i più diffusi anche per il fatto che la loro tecnologia costruttiva permette di avere dei costi produttivi minori rispetto ai modelli MPPT.

Il regolatore di carica PWM trasferisce l’energia dai moduli fotovoltaici alle batterie tramite impulsi di corrente. Durante questi impulsi la tensione dei moduli fotovoltaici viene portata alla tensione di batteria, per questo motivo il valore di tensione può essere minore rispetto al valore di tensione di massima potenza (Vmp) del modulo fotovoltaico.

Con questo tipo di regolatori di carica non è possibile utilizzare dei pannelli a 24Volt per caricare batterie a 12Volt;

Che cos'è un regolatore di carica solare MPPT?

MPPT è un acronimo che sta per **Maximum Power Point Tracking.**

Vuol dire che il regolatore di carica è in grado di inseguire costantemente il punto di massima potenza che il pannello è in grado di erogare in quel momento, a seconda dell'irraggiamento solare.

Quali sono i principali vantaggi?

1) Maggior corrente di ricarica erogata alla batteria

I regolatori MPPT sono infatti in grado di utilizzare tutta la potenza generata dal pannello per caricare la batteria, a differenza dei regolatori tradizionali PWM che inviano alla batteria la corrente generata dal pannello.

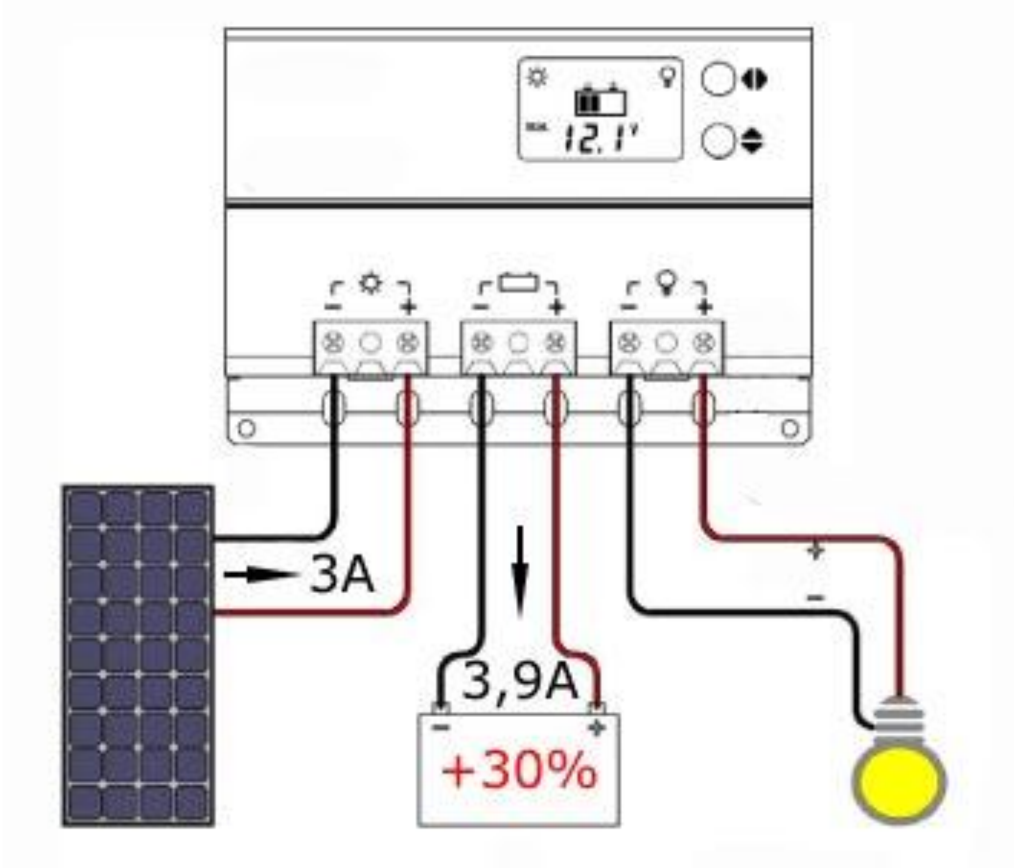
Per capire questo concetto, occorre innanzitutto specificare che la potenza di un pannello è il risultato della seguente moltiplicazione; (Corrente erogata dal pannello) x (Tensione generata dal pannello)

La tensione di lavoro generata dal pannello è tipicamente intorno ai 16-18V (*non* 12V, come la tensione di batteria): questo surplus di tensione non viene considerato nei regolatori di tensione tradizionali, mentre nei regolatori MMPT sì: vediamo come.

Ipotizziamo che la corrente generata da un pannello fotovoltaico sia, in una certa situazione, 3A: con un regolatore PWM tradizionale la corrente che viene trasferita alla batteria per la ricarica è pari a 3A.

Un regolatore MPPT analizza invece la potenza generata dal pannello (P = V x I, come detto prima), e considera quindi anche la tensione del pannello: se pertanto supponiamo che la tensione del pannello sia in quel momento 17V la potenza erogata dal pannello è 17V x 3A= 51W

Se la tensione di batteria è di 13V, considerando la massima potenza di 51W, la corrente di carica che verrà trasmessa alla batteria, è 51W/13V= 3,9 A.

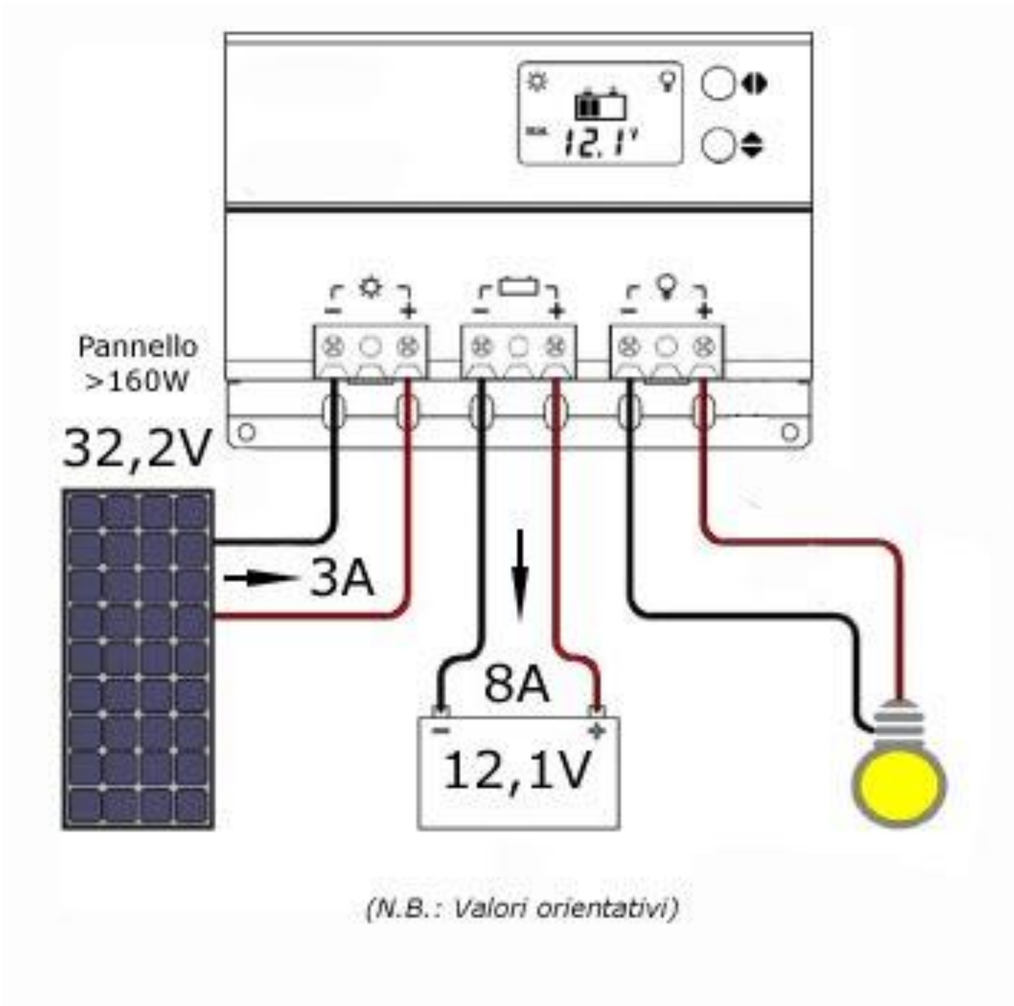


Notiamo quindi che la batteria sarà caricata con una corrente pari a **3,9A** con il regolatore MPPT, anziché **3A** con un regolatore tradizionale, e la ricarica avverrà pertanto con una rapidità maggiore del 30%, a parità di pannello e di corrente erogata. In pratica è come se utilizzassimo un pannello da 130W anziché uno da 100W, quindi il maggior costo di un regolatore MPPT viene bilanciato dal risparmio sul costo del pannello.

2) Ampio range di tensione in input (fino a 100V, secondo i modelli): questa caratteristica genera ad esempio la possibilità di **caricare una batteria 12V con un pannello progettato per lavorare a 24V**, senza perdita di potenza. Infatti, riprendendo l'esempio di prima, ipotizziamo di usare un pannello progettato per lavorare a 24V, che ha valori di tensione di lavoro tipici di 32-36V (valore tipico per potenza pannello superiore a 160W) Vediamo che cosa accade con corrente erogata di 3A:

- la potenza erogata dal pannello è 32,2V x 3A=96,6W

- la corrente di carica della batteria corrispondente ad esempio a 12,1V di tensione della batteria è 96,6W/12,1V= 7,98 A



Notiamo come con una corrente di 3A prodotta dal pannello a 34V riusciamo a caricare la batteria 12Vcon c.a. 8A, grazie al lavoro del regolatore MPPT. Un regolatore classico PWM non avrebbe effettuato questo innalzamento di corrente, e si sarebbe limitato a trasferire i 3A generati dal pannello, che si sarebbe quindi comportato come un pannello di metà potenza.

Anche in questo caso il maggior costo del regolatore MPPT viene bilanciato dal fatto che un pannello da 180W costa meno di 2 pannelli da 110W, ma che la corrente di carica alla batteria è la stessa.

SCELTA REGOLATORE

Hai bisogno di un regolatore di carica per il tuo impianto fotovoltaico ma non sai quale scegliere? Il mercato offre diversi tipi di regolatori di carica solari a diversi prezzi. Ma quale è quello più adatto a te? Risulta quindi molto importante conoscere le loro caratteristiche ed il loro funzionamento in modo da fare **un acquisto sicuro e duraturo**.

La scelta del giusto regolatore di carica per il tuo impianto fotovoltaico va fatta in base al tipo di pannelli e alla batteria che desideri installare. Se durante la progettazione del tuo

impianto fotovoltaico ad isola hai deciso di scegliere determinati pannelli anzichè altri è bene sapere che questa scelta può suggerire un regolatore anzichè un altro.
I nostri regolatori di carica sono di due tecnologie: **mppt** e **pwm**.

Dove usare un regolatore mppt e dove usare uno pwm?

Come abbiamo detto, la scelta della tecnologia del regolatore di carica dipende sia dal tipo di pannelli che abbiamo o che vogliamo installare sia dal banco batterie. Il regolatore pwm costa normalmente di meno rispetto ad un regolatore mppt, ma il regolatore mppt è in grado di **sfruttare pienamente** un pannello fotovoltaico di tensione ben superiore al banco batterie e quindi consente di produrre maggiore energia rispetto ad un regolatore pwm.
Se la tensione del pannello è di poco superiore a quella della batteria (tipico caso di un pannello 12V a 30 celle e batteria 12V), il regolatore pwm è consigliato in quanto ha un rendimento giornaliero in questo caso simile all'mppt. Di seguito quindi abbiamo fatto una **tabella** molto semplice dove troverete quale tecnologia del regolatore di carica usare in base a:

1) Numero di celle che compongono i vostri pannelli

2) Tensione del banco batterie che volete ricaricare

Pannelli e Batterie	Tipo di Regolatore
Pannelli a 36 celle e Batterie 12V	MPPT
Pannelli a 48 celle e Batterie 12V/24V	MPPT
Pannelli a 54 celle e Batterie 12V/24V	MPPT
Pannelli a 72 celle e Batterie 12V/24V	MPPT
Pannelli a 144 celle e Batterie 48V	MPPT
Pannelli a 30 celle e Batterie 12V	PWM
Pannelli a 60 celle e Batterie 24V	PWM
Pannelli a 120 celle e Batterie 48V	PWM

Come capire le tensioni dei pannelli in funzione delle loro celle?

Celle dei Pannelli	Tensione nominale	Tensione a circuito aperto
30 celle	12V	18V
36 celle	12V	21V
48 celle	18V	30V
54 celle	18V	33V
60 celle	24V	36V
72 celle	24V	42V
120 celle	48V	72V

144 celle	48V	84V

Come si comportano i due regolatori?

Ed ora vediamo due foto che abbiamo scattato per mostrarvi il comportamento della corrente nel regolatore di carica pwm PR3030 e nel regolatore di carica mppt Solarix. Come pannello fotovoltaico abbiamo utilizzato un pannello da 100W in silicio monocristallino. L'angolazione del pannello non era proprio perpendicolare ai raggi solari per un bisogno "fotografico". La batteria è una batteria della Fiamm al piombo-acido da 12V.

1) Regolatore di carica pwm PR3030

Come è visibile dalla foto, in uscita dal pannello abbiamo una corrente di 1,60A che viene usata quasi completamente dal regolatore pwm (1,57A) per ricaricare la batteria da 12V.

Il regolatore PR3030 può sopportare correnti fino a 30A e presenta anche la funzione di visualizzazione della percentuale di carica della batteria. In questo caso ci informa che la batteria è carica al 76%.

2) Regolatore di carica mppt Solarix

A differenza del regolatore pwm che considera solo la corrente al fine della carica, **il regolatore mppt Solarix considera tutta la potenza** del pannello fotovoltaico (quindi tensione e corrente). Infatti la differenza tra la tensione erogata dal pannello (esempio 36V) e la tensione necessaria alla batteria in quell'istante (esempio 14V) non viene persa ma viene trasformata dal regolatore mppt in corrente utile al processo di ricarica.

Dalla foto si vede che la corrente in uscita dal pannello è di 1,68A, ma la corrente che va alla batteria è addirittura di 2,07A. Con il regolatore di carica mppt Solarix utilizziamo tutta la potenza del pannello!

Solar Charge Controller Basics

What is a Solar Charge Controller?

A charge controller or charge regulator is basically a voltage and/or current regulator to keep batteries from overcharging. It regulates the voltage and current coming from the solar panels going to the battery. Most "12 volt" panels put out about 16 to 20 volts, so if there is no regulation the batteries will be damaged from overcharging. Most batteries need around 14 to 14.5 volts to get fully charged.

Do I always need a charge controller?

Not always, but usually. Generally, there is no need for a charge controller with the small maintenance, or trickle charge panels, such as the 1 to 5-watt panels. A rough rule is that if the panel puts out about 2 watts or less for each 50 battery amp-hours, then you don't need one.

For example, a standard flooded golf car battery is around 210 amp-hours. So to keep up a series pair of them (12 volts) just for maintenance or storage, you would want a panel that is around 4.2 watts. The popular 5-watt panels are close enough, and will not need a controller. If you are maintaining AGM deep cycle batteries, such as the Concorde Sun Xtender then you can use a smaller 2 to 2-watt panel.

Why 12 Volt Panels are 17 Volts?

The obvious question then comes up - "why aren't panels just made to put out 12 volts". The reason is that if you do that, the panels will provide power only when cool, under perfect conditions, and full sun. This is not something you can count on in most places. The panels need to provide some extra voltage so that when the sun is low in the sky, or you have heavy haze, cloud cover, or high temperatures*, you still get some output from the panel. A fully charged "12-volt" battery is around 12.7 volts at rest (around 13.6 to 14.4 under charge), so the panel has to put out at least that much under worst-case conditions.

*Contrary to intuition, solar panels work best at cooler temperatures. Roughly, a panel rated at 100 watts at room temperature will be an 83 watt panel at 110 degrees.

The charge controller regulates this 16 to 20 volts output of the panel down to what the battery needs at the time. This voltage will vary from about 10.5 to 14.6, depending on the state of charge of the battery, the type of battery, in what mode the controller is in, and temperature. (see complete info on battery voltages in our battery section).

Using High Voltage (grid tie) Panels With Batteries

Nearly all PV panels rated over 140 watts are NOT standard 12-volt panels, and cannot (or at least should not) be used with standard charge controllers. Voltages on grid tie panels vary quite a bit, usually from 21 to 60 volts or so. Some are standard 24-volt panels, but most are not.

WHAT HAPPENS WHEN YOU USE A STANDARD CONTROLLER

Standard (that is, all but the MPPT types), will often work with high voltage panels if the maximum input voltage of the charge controller is not exceeded. However, ***you will lose a lot of power*** - from 20 to 60% of what your panel is rated at. Charge controls take the output of the panels and feed current to the battery until the battery is fully charged, usually around 13.6 to 14.4 volts. A panel can only put out so many amps, so while the voltage is reduced from say, 33 volts to 13.6 volts, the amps from the panel cannot go higher than the rated amps - so with a 175 watt panel rated at 23 volts/7.6 amps, you will only get 7.6 amps @ 12 volts or so into the battery. Ohms Law tells us that watts are volts x amps, so your 175-watt panel will only put about 90 watts into the battery.

USING AN MPPT CONTROLLER WITH HIGH VOLTAGE PANELS

The only way to get full power out of high voltage grid tie solar panels is to use an MPPT controller. See the link above for detailed information on MPPT charge controls. Since most MPPT controls can take up to 150 volts DC (some can go higher, up to 600 VDC) on the solar panel input side, you can often series two or more of the high voltage panels to reduce wire loss or to use smaller wire. For example, with the 175-watt panel mentioned above, 2 of them in series would give you 46 volts at 7.6 amps into the MPPT controller, but the controller would convert that down to about 29 amps at 12 volts.

Charger Controller Types

Charge controls come in all shapes, sizes, features, and price ranges. They range from the small 4.5 amp (Sunguard) control, up to the 60 to 80 amp MPPT programmable controllers with computer interface. Often, if currents over 60 amps are required, two or more 40 to 80 amp units are wired in parallel. The most common controls used for all battery based systems are in the 4 to 60 amp range, but some of the new MPPT controls such as the Outback Power FlexMax go up to 80 amps.

CHARGE CONTROLS COME IN 3 GENERAL TYPES (WITH SOME OVERLAP):

Simple 1 or 2 stage controls which rely on relays or shunt transistors to control the voltage in one or two steps. These essentially just short or disconnect the solar panel when a certain voltage is reached. For all practical purposes these are dinosaurs, but you still see a few on old systems - and some of the super cheap ones for sale on the internet. Their only real claim to fame is their reliability - they have so few components, there is not much to break.

3-stage and/or PWM such Morningstar, Xantrex, Blue Sky, Steca, and many others. These are pretty much the industry standard now, but you will occasionally still see some of the older shunt/relay types around, such as in the very cheap systems offered by discounters and mass marketers.

Maximum power point tracking (MPPT), such as those made by Midnite Solar, Xantrex, Outback Power, Morningstar and others. These are the ultimate in controllers, with prices to match - but with efficiencies in the 94% to 98% range, they can save considerable money on larger systems since they provide 10 to 30% more power to the battery. For more information, see our article on MPPT.

Most controllers come with some kind of indicator, either a simple LED, a series of LED's, or digital meters. Many newer ones, such as the Outback Power, Midnite Classic, Morningstar MPPT, and others now have built in computer interfaces for monitoring and control. The simplest usually have only a couple of small LED lamps, which show that you have power and that you are getting some kind of charge. Most of those with meters will show both voltage and the current coming from the panels and the battery voltage. Some also show how much current is being pulled from the LOAD terminals.

All of the charge controllers that we stock are 3 stage PWM types, and the MPPT units. (in reality, "4-stage" is somewhat advertising hype - it used to be called equalize, but someone decided that 4 stage was better than 3). And now we even see one that is advertised as "5-stage"....

What is Equalization?

Equalization does somewhat what the name implies - it attempts to equalize - or make all cells in the battery or battery bank of exactly equal charge. Essentially it is a period of overcharge, usually in the 15 to 15.5 volt range. If you have some cells in the string lower than others, it will bring them all up to full capacity. In flooded batteries, it also serves the important function of stirring up the liquid in the batteries by causing gas bubbles. Of course, in an RV or boat, this does not usually do much for you unless you have been parked for months, as normal movement will accomplish the same thing. Also, in systems with small panels or oversized battery systems you may not get enough current to really do much bubbling. In many off-grid systems, batteries can also be equalized with a generator+charger.

What is PWM?

Quite a few charge controls have a "PWM" mode. PWM stands for Pulse Width Modulation. PWM is often used as one method of float charging. Instead of a steady output from the controller, it sends out a series of short charging pulses to the battery - a very rapid "on-off" switch. The controller constantly checks the state of the battery to determine how fast to send pulses, and how long (wide) the pulses will be. In a fully charged battery with no load, it may just "tick" every few seconds and send a short pulse to the battery. In a discharged battery, the pulses would be very long and almost continuous, or the controller may go into "full on" mode. The controller checks the state of charge on the battery between pulses and adjusts itself each time.

The downside to PWM is that it can also create interference in radios and TV's due to the sharp pulses that it generates. If you are having noise problems from your controller, see this page.

What is a Load, or "Low Voltage Disconnect" output?

Some controllers also have a "LOAD", or LVD output, which can be used for smaller loads, such as small appliances and lights. The advantage is that the load terminals have a low voltage disconnect, so it will turn off whatever is connected to the load terminals and keep from running the battery down too far. The LOAD output is often used for small non-critical loads, such as lights. A few, such as the Schneider Electric C12, can also be used as a lighting controller, to turn lights on at dark, but the Morningstar SLC lighting controller is usually a better choice for that. ***Do not use the LOAD output to run any but very small inverters. Inverters can have very high surge currents and may blow the controller.***

Most systems do not need the LVD function - it can drive only smaller loads. Depending on the rating of the controller, this may be from 6 to 60 amps. You cannot run any but the smallest inverter from the LOAD output. On some controllers, such as the Morningstar SS series, the load output can be used to drive a heavy duty relay for load control, gen start etc. The LOAD or LVD output is most often used in RV & remote systems, such as camera, monitor, and cell phone sites where the load is small and the site is unattended.

What are the "Sense" terminals on my controller?

Some charge controllers have a pair of "sense" terminals. Sense terminals carry very low current, around 1/10th of a milliamp at most, so there is no voltage drop. What it does is "look" at the battery voltage and compares it to what the controller is putting out. If there is a voltage drop between the charge controller and the battery, it will raise the controller output slightly to compensate.

These are only used when you have a long wire run between the controller and the battery. These wires carry no current, and can be pretty small - #20 to #16 AWG. We prefer to use #16 because it is not easily cut or squished accidentally. They attach to the SENSE terminals on the controller, and onto the same terminals as the two charging wires at the battery end.

What is a "Battery System Monitor"?

Battery system monitors, such as the Bogart Engineering TriMetric 2025A are not controllers. Instead, they monitor your battery system and give you a pretty good idea of your battery condition, and what you are using and generating. They keep track of the total amp-hours into and out of the batteries, and the battery state of charge, and other information. They can be very useful for medium to large systems for tracking exactly what your system is doing with various charging sources. They are somewhat overkill for small systems, but are kind of a fun toy if you want to see what every amp is doing :-). TriMetric's new PentaMetric model also has a computer interface and many other features.
For a complete list of all our charge controllers, to check pricing, or to order online, see our Charge Controller page on our web store. For battery monitors, meters, and shunts see our Meters & Monitors page there.

All About Maximum Power Point Tracking (MPPT) Solar Charge Controllers

What is an MPPT Charge Controller?

This section covers the theory and operation of "Maximum Power Point Tracking" as used in solar electric charge controllers.

An MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. To put it simply, they convert a higher voltage DC output from solar panels (and a few wind generators) down to the lower voltage needed to charge batteries.

(These are sometimes called "power point trackers" for short - not to be confused with PANEL trackers, which are a solar panel mount that follows, or tracks, the sun).

So what do you mean by "optimize"?

Solar cells are neat things. Unfortunately, they are not very smart. Neither are batteries - in fact, batteries are downright stupid. Most PV panels are built to put out a nominal 12 volts. The catch is "nominal". In actual fact, almost all "12-volt" solar panels are designed to put out from 16 to 18 volts. The problem is that a nominal 12-volt battery is pretty close to an actual 12 volts - 10.5 to 12.7 volts, depending on state of charge. Under charge, most batteries want from around 13.2 to 14.4 volts to fully charge - quite a bit different than what most panels are designed to put out.

OK, so now we have this neat 130-watt solar panel. Catch #1 is that it is rated at 130 watts at a particular voltage and current. The Kyocera KC-130 is rated at 7.39 amps at 17.6 volts. (7.39 amps times 17.6 volts = 130 watts).

Now the Catch 22

WHY 130 WATTS DOES NOT EQUAL 130 WATTS. WHERE DID MY WATTS GO?

So what happens when you hook up this 130-watt panel to your battery through a regular charge controller?

UNFORTUNATELY, WHAT HAPPENS IS NOT 130 WATTS.

Your panel puts out 7.4 amps. Your battery is setting at 12 volts under charge: 7.4 amps times 12 volts = 88.8 watts. You lost over 41 watts - but you paid for 130. That 41 watts are not going anywhere, it just is not being produced because there is a poor match between the panel and the battery. With a very low battery, say 10.5 volts, it's even worse - you could be losing as much as 35% (11 volts x 7.4 amps = 81.4 watts. You lost about 48 watts.

One solution you might think of - why not just make panels so that they put out 14 volts or so to match the battery?

Catch #22a is that the panel is rated at 130 watts at full sunlight at a particular temperature (STC - or standard test conditions). If the temperature of the solar panel is high, you don't get 17.4 volts. At the temperatures seen in many hot climate areas, you might get under 16 volts. If you started with a 15-volt panel (like some of the so-called "self-regulating" panels), you are in trouble, as you won't have enough voltage to put a charge into the battery. Solar panels have to have enough leeway built in to perform under the worst of conditions. The panel will just sit there looking dumb, and your batteries will get even stupider than usual.

Nobody likes a stupid battery.

What is Maximum Power Point Tracking?

There is some confusion about the term "tracking":

Panel tracking - this is where the panels are on a mount that follows the sun. The most common are the Zomeworks. These optimize output by following the sun across the sky for maximum sunlight. These typically give you about a 15% increase in winter and up to a 35% increase in summer.

This is just the opposite of the seasonal variation for MPPT controllers. Since panel temperatures are much lower in winter, they put out more power. And winter is usually when you need the most power from your solar panels due to shorter days.

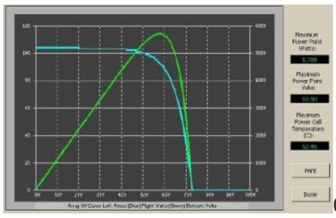
Maximum Power Point Tracking is electronic tracking - usually digital. The charge controller looks at the output of the panels and compares it to the battery voltage. It then figures out what is the best power that the panel can put out to charge the battery. It takes this and converts it to best voltage to get maximum AMPS into the battery. (Remember, it is Amps into the battery that counts). Most modern MPPT's are around 93-97% efficient in the conversion. You typically get a 20 to 45% power gain in winter and 10-15% in summer. Actual gain can vary widely depending weather, temperature, battery state of charge, and other factors.

Grid tie systems are becoming more popular as the price of solar drops and electric rates go up. There are several brands of grid-tie only (that is, no battery) inverters available. All of these have built in MPPT. Efficiency is around 94% to 97% for the MPPT conversion on those.

How Maximum Power Point Tracking works

Here is where the optimization or maximum power point tracking comes in. Assume your battery is low, at 12 volts. An MPPT takes that 17.6 volts at 7.4 amps and converts it down so that what the battery gets is now 10.8 amps at 12 volts. Now you still have almost 130 watts, and everyone is happy.

Ideally, for 100% power conversion you would get around 11.3 amps at 11.5 volts, but you have to feed the battery a higher voltage to force the amps in. And this is a simplified explanation - in actual fact, the output of the MPPT charge controller might vary continually to adjust for getting the maximum amps into the battery.



On the left is a screenshot from the Maui Solar Software "PV-Design Pro" computer program (click on the picture for full-size image). If you look at the green line, you will see that it has a sharp peak at the upper right - that represents the maximum power point. What an MPPT controller does is "look" for that exact point, then does the voltage/current conversion to change it to exactly what the battery needs. In real life, that peak moves around continuously with changes in light conditions and weather.

An MPPT tracks the maximum power point, which is going to be different from the STC (Standard Test Conditions) rating under almost all situations. Under very cold conditions a 120-watt panel is actually capable of putting over 130+ watts because the power output goes up as panel temperature goes down - but if you don't have some way of tracking that power point, you are going to lose it. On the other hand under very hot conditions, the power drops - you lose power as the temperature goes up. That is why you get less gain in summer.

MPPT's are most effective under these conditions:

Winter, and/or cloudy or hazy days - when the extra power is needed the most.

- *Cold weather - solar panels work better at cold temperatures, but without an MPPT you are losing most of that. Cold weather is most likely in winter - the time when sun hours are low and you need the power to recharge batteries the most.*
- *Low battery charge - the lower the state of charge in your battery, the more current an MPPT puts into them - another time when the extra power is needed the most. You can have both of these conditions at the same time.*
- *Long wire runs - If you are charging a 12-volt battery, and your panels are 100 feet away, the voltage drop and power loss can be considerable unless you use very large wire. That can be very expensive. But if you have four 12 volt panels wired in series for 48 volts, the power loss is much less, and the controller will convert that high voltage to 12 volts at the battery. That also means that if you have a high voltage panel setup feeding the controller, you can use much smaller wire.*

Ok, so now back to the original question - What is an MPPT?

How a Maximum Power Point Tracker Works:

The Power Point Tracker is a high-frequency DC to DC converter. They take the DC input from the solar panels, change it to high-frequency AC, and convert it back down to a different DC voltage and current to exactly match the panels to the batteries. MPPT's operate at very high audio frequencies, usually in the 20-80 kHz range. The advantage of high-frequency circuits is that they can be designed with very high-efficiency transformers and small components. The design of high-frequency circuits can be very tricky because of the problems with portions of the circuit "broadcasting" just like a radio transmitter causing radio and TV interference. Noise isolation and suppression becomes very important.

There are a few non-digital (that is, linear) MPPT's charge controls around. These are much easier and cheaper to build and design than the digital ones. They do improve efficiency somewhat, but overall the efficiency can vary a lot - and we have seen a few lose their "tracking point" and actually get worse. That can happen occasionally if a cloud passed over the panel - the linear circuit searches for the next best point but then gets too far out on the deep end to find it again when the sun comes out. Thankfully, not many of these around anymore.

The power point tracker (and all DC to DC converters) operates by taking the DC input current, changing it to AC, running through a transformer (usually a toroid, a doughnut looking transformer), and then rectifying it back to DC, followed by the output regulator. In most DC to DC converters, this is strictly an electronic process - no real smarts are involved except for some regulation of the output voltage. Charge controllers for solar panels need a lot more smarts as light and temperature conditions vary continuously all day long, and battery voltage changes.

Smart power trackers

All recent models of digital MPPT controllers available are microprocessor controlled. They know when to adjust the output that it is being sent to the battery, and they actually shut down for a few microseconds and "look" at the solar panel and battery and make any needed adjustments. Although not really new (the Australian company AERL had some as early as 1985), it has been only recently that electronic microprocessors have become cheap enough to be cost-effective in smaller systems (less than 1 KW of the panel). MPPT charge controls are now manufactured by several companies, such as Outback Power, Xantrex XW-SCC, Blue Sky Energy, Apollo Solar, Midnite Solar, Morningstar and a few others.