Maximum Powerpoint Trackers

What is a MPPT?
A 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, DC motor, or DC pump. (These are usually called power trackers or MPPT's for short - not to be confused with PANEL trackers, which are a top-of-pole panel mount that follows, or tracks, the sun). MPPT controllers are a refinement of the old LCB (linear current booster) controls often still used on solar powered pumps.

Solar cells and lead acid batteries are not smart devices. They have different voltage and current characteristics and requirements.
Most 12V PV panels are built to put out a nominal 12 volts. The catch is *nominal*. In actual fact, almost all are designed to put out from 15 to 20 volts, with most being in the 16.0 to 18.0 volt range. The catch is, is that a nominal 12 volt battery is pretty close to an actual 12 volts - 10.5 to 13.2 volts, depending on state of charge. Under charge, most batteries want from around 13.4 to 14.4 volts - quite a bit different than what most panels are designed to put out.
The power output of a solar panel varies almost directly with the amount of sunlight - but the voltage and current do not. The current drops off much faster than the voltage until you reach very low light levels. Thus under low light conditions the panel may be putting out 16 volts, but the amperage will be very low.
For example we will take a standard 75 watt panel. It is rated at 75 watts at a particular voltage and current. For example the Shell SP-75 is rated at 4.4 amps at 17 volts - 4.4 times 17 = 75 watts. Other brands and types are rated the same way.

Why 75 Watts does NOT equal 75 watts

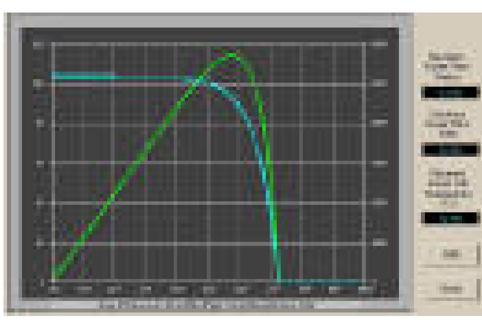
So what happens when you hook up this 75 watt panel to a battery? Unfortunately, what happens is **not** 75 watts. Your panel puts out 4.4 amps. Your battery regulator setting is at 14 volts under charge: 4.4 amps times 14 volts = 61.6 watts. You lost 14 watts, or almost 20% of your power. That 14 watts is not going anywhere, it just is not being produced because there is a poor match between the panel and the battery and the energy is being lost as heat in the regulator and in the panel. With a very low battery, say 11 volts, it's even worse - you could be losing as much as 35% (11 volts x 4.4 amps = 48 watts. One solution that pops to mind is - why not just make panels so that they put out 14 volts or so to match the battery?

The panel is rated at 75 watts at full sunlight at a particular temperature (25C). If you have a cloudy day, or the temperature is high, you don't get 17 volts. (actually, temperature is the most important factor, as lowered light reduces the AMPS quite a bit, but the voltage only a little, up to a point). At the temperatures seen in many hot climate areas, you might get 15 volts. If you started with 15 volts (as in 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.

What does a Maximum Power Point Tracker (MPPT) do?

A MPPT looks at the output of the panels, and compares it to the battery voltage. It then uses an algorithm to calculate what is the absolute best power that the panel can put out. It takes this and converts it to the best voltage to get maximum AMPS into the battery. (Remember, it is Amps into the battery that counts). Most MPPT's are around 92-97% efficient (The Outback MX-60 is 97-99% efficient) in the conversion. You typically get a 20 to 45% power gain in winter and 10-20% in summer over using a standard PWM regulator.

Here is where the optimization, or maximum power point tracking comes in. A MPPT takes that 17 volts at 4.4 amps and converts it, so that what it puts out to the battery is no longer 4.4 amps at 17 volts, but 5.77 amps at 13 volts. Now you still have 75 watts, and everyone is happy. (Actually, you get about 72 watts, as MPPT's are not quite 100% efficient). In an extreme case, such as a fully discharged battery at 10.5 volts, you would get nearly 7 amps at 10.5 volts out of the MPPT into the battery.
A 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 75 watt panel is actually capable of putting over 80 watts because the output goes up as 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.



A graphical picture of what the maximum power point really means

On the left is a screen shot from the **Maui Solar Software** "PV-Design Pro" computer program 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 as far as voltage and current. These calculations are done regularly and in milliseconds.

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 a 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 the most.

Low battery charge - the lower the state of charge in your battery, the more current a 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.

Some "budget" MPPT's on the market don't give you, as much you would hope for. The reason is efficiency. So you gain 25% by adding a MPPT - that does not help you much if your MPPT is 85% efficient. You've only gained about 5 watts - not much to get excited about. It's an unfortunate fact of life that so far the only MPPT's we have seen that really approaches 98% under all conditions is the Outback Power MX60 and the AERL Maximizer. Although nobody (Except Outback now) has been able to match the AERL performance in the 15 years that they have been selling them, their market has always been pretty small because they are very expensive (3 to 8 times other brands). The new MX60 MPPT 60 amp charge controller made by Outback products is rated at 97 to 99% efficiency.
The simple fact is, MPPT's are much better now than it was even two or three years ago. Because of the very wide range of conditions that solar panels can be subjected to, only sophisticated (meaning expensive) microprocessor controlled circuitry can do a good job of power conversion under all conditions. Simple analog MPPT's, such as pump controllers, will still have a place but for the most part the MPPT manufacturers have all shifted to digital. Right now the major barrier to widespread use in smaller systems is that MPPT controllers are more expensive than the standard series PWM controllers. Depending on which MPPT controller you are looking at, they start to get cost effective with solar array sizes in the 400 to 500 watt range - that is, the extra cost of the controller is cheaper than adding more panel watts.

Ok, so now back to the original question:
What is a MPPT?

The MX-60 is a high frequency DC to DC converter. It takes the DC input from the solar panels, change it to AC, and convert it to a different DC voltage and current to exactly match the panels to the batteries. MPPT's operate at very high audio frequencies, in the 20-50 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 frequencies circuits can be very tricky because the problems with portions of the circuit "broadcasting" just like a radio transmitter. Noise isolation and suppression becomes very important. The

advantage of using high frequency is that high efficiency is easier to achieve, and component parts, especially transformers, can be made much smaller.
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 converters, this is strictly an electronic process - no real smarts are involved except for some regulation of the output voltage or current. This is the type of conversion used in some analog MPPT's such as the RV Power Products. You don't get quite the full efficiency as you do in the "smart" ones, but the price is considerably less - and you still gain 10 to 25% under most conditions. The Outback Power and AERL MPPT's are microprocessor controlled. The Outback MX60 has a very nice computer (RS485) computer interface. The AERL has no interface, however they do have some models that will match almost anything to anything, up to 185 volts - the AERL units are rather specialized, while the Outback Power units are well into the mainstream for standard installations.

Smart MPPT's

Most new models of 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 (AERL had some as early as 1985), it has been only recently that electronic chips and microprocessors have become cheap enough to be cost effective in smaller systems (less than 2 KW of panel). New units, such as the Outback Power MX-60 (microprocessor) units seem to have finally broken the cost/benefit barrier, although still too expensive for small one or two panel systems.