Using a solar generator

I have owned a mid-sized portable power station for a few years now, but recently took the leap and bought some solar panels to use with it to create a solar generator. Since my goal here is emergency preparedness, I went with folding, portable solar panels, enabling them to be easily transported and deployed wherever they are needed.

I'm not guaranteeing that everything I'm doing here is the best way to do it; far from it. This is just a layout of what I did in particular, and how I arrived at the decisions I made, followed by a bunch of background information in the hopes that it will be useful to you.

Equipment used for this:

- Pecron E1500 Pro power station
- Two Predator 200W folding portable solar panels
- Two Bateria 30' 10 gauge MC4 extension sets
- MC4 to GX16 adapter (which was included with the power station)

Note that the MC4 extension sets were shipped as two, 30', single-conductor cords, one red, one black, with MC4 connectors on each end. After unpacking, I took the two cords in the set and twisted them together, so that each end had one plug and one socket, since I'm always going to be running them side-by-side. I repeated this for the second set.

Setup

The panels I'm using have a 20V output, and the power station wants 32-95V on its MVDC input. To get there, I am using two panels wired in series, to raise the voltage to 40V.

It's important for safety and for the longevity of the connectors that they not be connected or disconnected while there is power in the system. For this reason, I will keep the panels folded up so that no light reaches them while I am wiring or unwiring them. If I had used rigid panels, the solution would be to cover the panels with a heavy tarp, again, to ensure that no light reaches them.

From here, I can take the positive (red) wire from one of the solar panels and snap it onto the negative (black) wire of the other. This is how series wiring is done. This leaves one red wire from the second panel, and one black wire from the first panel still unconnected. *Do not* plug them together – that would create a short circuit, and anyway they're needed for the next step.

Taking one of the MC4 extension sets, I can then find the end where the red wire is the socket. I'll take the still-unconnected red wire from the second panel and plug it into the red wire of the extension. I'll take the still-unconnected black wire from the first panel and plug it into the black wire of the extension. I'll run the extension to wherever I've set up the power station, adding more if needed.

At the power station, the MC4 connectors on the end of the extension connect to the adapter that fits the power station and the adapter plugs into the power station.

At this point, I can open the panels, or uncover them, and that should wake up the charging circuits in the power station. It should begin seeking the best power level to draw from the panels and charging the batteries.

Fine tuning

Solar panels will produce power with whatever light hits them, however, for maximum output, the panels should be oriented so that the flat face of the panels faces the sun as directly as possible.

At a minimum, the panels can be placed flat on the ground, and they will collect sunlight. This is the least-effort approach. It will get the job done, but not well. That's the "good" approach. You can improve on this slightly by placing the panels on a southward-facing roof, however performance may still be less than optimal.

A second approach is found in the manual that came with my panels. It suggests that you should point the panels due south (assuming northern latitudes), and adjust the panels' elevation for your latitude and the current season. For Spring and Fall, the panels should be set at an angle equal to your latitude, raised by 15° for the Winter, or lowered by 15° for the Summer. This should yield a reasonably good output. That's the "better" approach.

Yet a third approach, but one which is going to be highly manual, is to periodically adjust the panels' positions throughout the day. The simplest way to do this is to use something that can be set on the panel that will give you a definitive 90° angle (I used a combination square for this) in both axes. If it casts a shadow on the panel, adjust the panel's position until it doesn't. That's the "best" approach.

Everything past this point is background information.

Definitions

Alternating Current, AC – An electrical flow in which the electrical charge reverses direction at a specified, regular rate. Common household appliances operate on *AC*, and *AC* is delivered to standard household outlets. In North America, the specified rate is 60 Hertz (Hz), or 60 cycles per second. Each cycle consists of two full reversals of the flow, along with smooth acceleration and deceleration, such that at the end of a cycle, the flow is exactly what it was at the start of the cycle.

Ampere, Amp, A – Unit of electrical *current*.

Current – The flow rate of electricity between two points. It indicates the amount of charge that passes a given point per second. This will dictate the required thickness (gauge) of conductors.

Direct Current, DC – An electrical flow in which electrical charge consistently moves from one pole (negative) to the other (positive). Batteries store DC; solar panels produce DC.

Kilowatt – 1000 *Watts*

Kilowatt-hour – 1000 *Watt-hours.*

Medium Voltage – This is *potential* in the range of 51 to 750 *volts*. Electricity operating in this range has lethal potential, but the lethality can be managed through the use of common connectors and fixtures that prevent the user from coming into contact with the live conductors. Shock, arc-flash and arc-blast hazards exist in this range, but are typically managed.

Medium Voltage Direct Current, MVDC – see *Medium Voltage* and *Direct Current*

Parallel – A wiring technique in which the positive wires from multiple *sources* or *sinks* are connected together, and the negative wires are likewise connected together. This wiring technique raises the system *current* without impacting the *potential*. The technique can also be used for sinks in AC circuits, however, it cannot be used for sources in AC circuits without synchronization (which is beyond the scope of this article).

Potential – The amount of energy carried by a given amount of electrical charge. Also sometimes called *tension* or *voltage*.

Power – The rate at which energy is transformed or moved from one place to another.

Series – A wiring technique in which the positive wire from one *source* or *sink* is connected to the negative wire of another *source* or *sink*. This wiring technique raises the system *potential* without affecting the *current.* The technique can also be used for sinks in AC circuits, however, it cannot be used for sources in AC circuits without synchronization (which is beyond the scope of this article).

Sink – A place where power goes to. The opposite is *source.*

Source – A place where power comes from. The opposite is *sink*.

Tension – See *potential*.

Volt, V – Unit of electrical *potential*.

Voltage – See *potential*.

Watt, W – Unit of *power*. While usually only used for electrical power in the US, it can also measure power in other forms. For instance 1 HP is the same as 746W.

Watt-hour, Wh – Unit of *energy*. This is the amount of energy that is moved when a power level of 1W is applied for 1 hour. **N.B.** this is “watt-hour” not “watt per hour.” We are multiplying, not dividing.

About power stations

A portable power station is a device that allows you to store a middling-to-large amount of electricity in a battery, and combines it with multiple ways to charge and use the battery. There are a number of manufacturers making these, including Pecron, Bluetti, Ecoflow, Renogy, Jackery, Predator, and others. From my observations, Jackery is probably the best known, to the point of practically being a synonym for power stations the way that Kleenex is for tissues, Velcro for hook and loop fasteners, etc. Ecloflow is what I've seen the most actually in the wild. Bluetti seem to be the best built. Pecron give you the greatest bang for the buck. Predator and Jackery are readily available on retail store shelves.

One of the important features you will find on the DC inputs of these power stations is called Maximum Power Point Tracking, or MPPT. This is the ability, when working with opportunistic power sources such as a solar panel, to adjust the charging rate so that it does not bog down the source.

As the charging rate increases, it will cause some drop in the source voltage. If the charging rate is too low, the power station is missing an opportunity. If it is too high, it can cause the voltage drop to be pronounced enough that the source is not operating at maximum efficiency. MPPT works to find the balance between these to extract as much power from your solar panels as possible.

The power statation I own is a Pecron E1500 Pro. There's a newer model called the E1500 LFP, which has superseded it and has some incremental improvements. Both have a battery capacity somewhere near 1500 watt-hours, both can charge from low-voltage DC (LVDC) at 12-18 volts, up to 100 watts; medium-voltage DC (MVDC) at 32-95 volts, up to 800 watts; or AC at 100-120 volts at up to 1000 watts. The two DC inputs both have MPPT.

In addition to the charging capability, the Pecron power station provides an array of DC outputs, including three 12V options, multiple USB options, wireless charging, and can also produce up to 2000W of 120V AC continuously, and 4000W in short bursts.

About solar panels

A photovoltaic cell or solar cell is a device which converts light that reaches it into electricity. One solar cell typically produces about 0.5 volts, at a power level that will vary by size and design.

A solar panel consists of an array of solar cells that have been arranged in a way to raise the voltage to a (hopefully) practical level, and provide a (hopefully) practical current level to go with it.

When looking at a solar panel's specifications, it has the following key characteristics:

- Operating voltage – important to note
- Open circuit voltage – also important
- Short circuit voltage – not strictly needed, but can be helpful
- Power output – important, but if it's not there, we can calculate it from current and voltage
- Short circuit current – important, but if it's not there, we can calculate it from power and voltage

- Efficiency – Interesting, but usually not important. This will usually be somewhere between 15-20%.
- Type – This will usually be either "amorphous," "polycrystalline" or "monocrystalline." This is interesting, but not usually important. It directly impacts the efficiency.

If you do not have the power output specified, first off, shame on the manufacturer's marketing department, because this is the most marketable number. You can simply multiply the operating voltage by the short circuit current and get this figure. If the operating voltage is not specified, you can substitute the short-circuit voltage, but this will inflate the figure slightly.

If you do not have the short circuit current, you can get this by dividing the power by the short circuit voltage, basically reversing the calculation I described in the last paragraph.

The panels I am using for this are the Predator 200W folding panel. Predator is a Harbor Freight store brand, and this is item number 70477. The panel has an operating voltage of 20V, and a short-circuit current of 11A.

You might have noticed that the input voltages on the power station in the last section are 12-18 and 32-95, and that 20 doesn't fall into either of those ranges. I solved this problem by getting two panels, and then wiring them in series, giving a 40V output. The short-circuit current remains 11A when wired this way.

About connectors

When working with common household current, many parts of the world, including all of North America, have the advantage of having a single type of connector that's used to plug things into the wall. The most common connector used in the US and Canada is called a NEMA 5-15 and there are some mostly-compatible variations on the 5-15 for various reasons . . . but you can generally expect that something marketed to North America can be plugged into the wall socket in a North American home. There was a time when that was not the case, but it was back in the first half of the 20th Century, and well behind us.

Not so with solar power DC connectors. While the solar power industry seems like it is converging on one particular connector, called an MC4, this is not really universal yet. A variety of other connectors, such as PowerPole may be found instead. As such, when you buy your panels and power station, you will need to take steps to ensure that you have adapters to get you from one thing to another.

It's also worth noting that MC4 connectors in particular are not great panel-mount connectors. They are designed and built to be used in-line on cables, and they're great for that, but it would be impractical to place one in a junction or control panel to connect a cord to. As such, they tend to be connected to endpoints either by hard-wiring a length of cable to the endpoint or by using an adapter to a panel-friendly connector.

In my particular case, the Predator solar panels have 10’ cords connecting the panel to MC4 connectors, and the Pecron power station comes with an adapter that will connect MC4 to a GX16 aviation connector to plug into the Pecron’s MVDC port. Pecron were kind enough to also include an adapter to go to a PowerPole connector that might be found on other equipment, and Predator were kind enough to include an adapter to connect MC4 to a 7909 plug for some other power stations, such as Jackery. Bottom line, adapters are going to be a part of the picture.

Extension cords

It is unlikely that you will want to put your solar panels and your power station in the same place. Solar panels must, by definition, be placed outside where the sunlight can reach them, exposing them to the weather. Most power stations are not designed to withstand weather, and so extension cords are a must.

The short-circuit current of your panels will tell you what weight these need to be, with 14 gauge for up to 15A, 12 gauge for up to 20A and 10 gauge for up to 30A. I bought two, 10 gauge MC4 extension cord sets, 30’ each, which is grossly overkill for the 11A rating of the panels, but this provides some future-proofing as well as reducing line loss. You don’t have to do that.

When the extension cord sets arrived, I was expecting them to be tandem cords like you find on many appliances; just bigger. It turns out that they are two, individual cords, one red, one black, with appropriate MC4 connectors on them. Since I am going to be using them to go to the same place at one time, I took some time to twist them together, and zip-tied the ends a short distance from the plugs. When doing this, make sure that both ends of the twisted pair have one plug and one socket. This is because the positive and negative connections will be opposite, with positive being a plug on the source and a socket on the sink; and negative being a plug on the sink and a socket on the source.

Final thought

Any piece of equipment that you have acquired in the name of emergency preparedness is only as good as your ability to use it. Gun owners go to the range. Radio operators get on the air. Firefighters go to drills. With few exceptions (such as fire extinguishers), you need to take out and use the equipment you bought for emergency preparedness, and use it from time to time. This is how you ensure that you know how it works, how to use it, and that it is in good and proper working order.

During the winter months, my power station is connected to my furnace, maintaining its full charge from the grid, and ready to provide the furnace with power if the lights go out. It means that I don’t have to worry about the pipes freezing because the heat will continue to operate for many hours. Now that I have the solar panels, and the warmer weather is upon us, I have been using the power station, *with* the solar panels, to power my lawnmower, my rototiller, and various power tools to do home improvement projects. It probably doesn’t appreciably reduce my utility bill, but what it *does* do is make sure that I know how to set this equipment up and use it when I need it.

Figure 1: Pecron E1500 Pro


Figure 2: MC4 extension cords


Figure 3: MC4 to GX16 adapter from Pecron


Figure 4: Close-up detail of MC4 connectors

Figure 5: GX16 socket


Figure 6: GX16 Plug

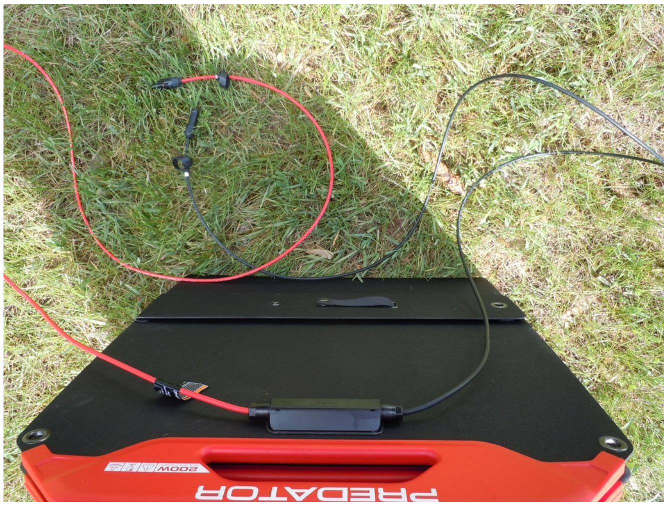

Figure 7: Rear of panel

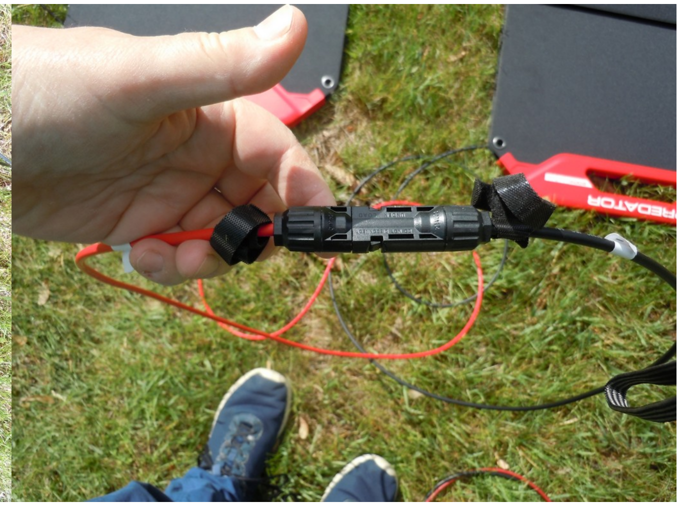

Figure 8: Connecting the panels in series

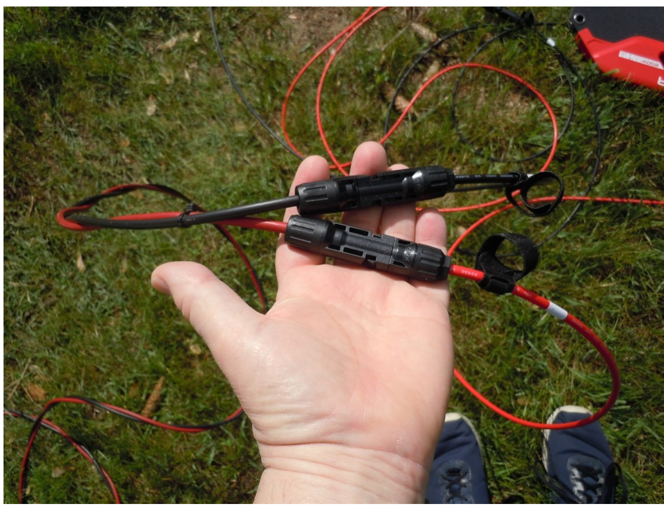

Figure 9: Connecting panels to extension

Figure 10: Panels deployed flat on the ground

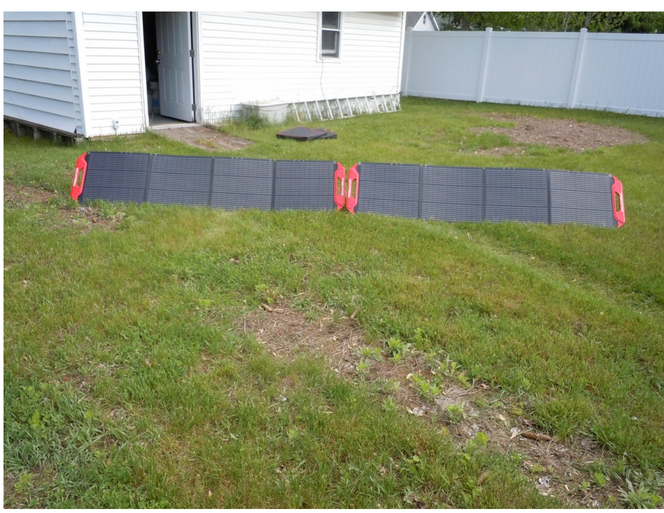

Figure 11: Panels propped up to face the sun

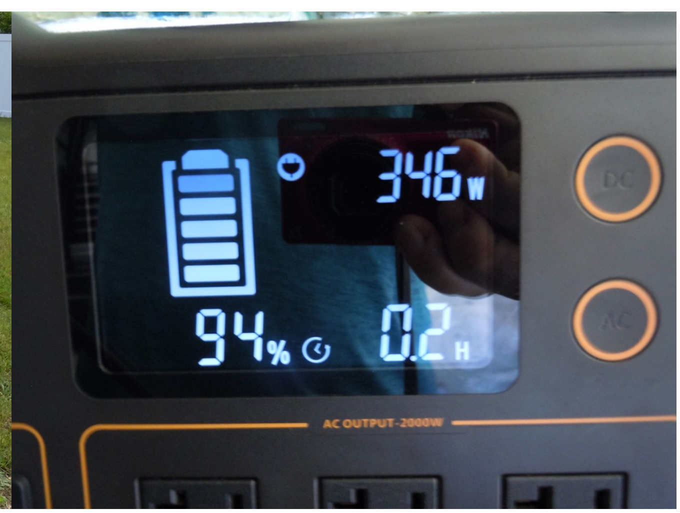

Figure 12: The payoff