

Field Guide – Practical System and Components

Developed by Tom Herman, GFT Ambassador and Presented by the National Greening Fire Team – Summer 2023



In this Field Guide . . .

Learn about modifications of your solar system in the field from the experience of Tom Herman, a Greening Fire Team Ambassador from Washington’s Department of Natural Resources.

Let’s leave the theory behind and get to where the rubber meets the road! We’ll start with pictures, descriptions, and specifications of the parts used. The beauty of Scalable Power is that you use what you have access to. These are things that have worked for GFT Ambassadors. Hopefully you can use them, and build on what GFT Ambassadors has done, and improve upon it.



Thunderbolt Solar 100-Watt Monocrystalline Solar Panel. *Photo by*

Distributor:	Harbor Freight Tools	Power:	100 Watts	Weight:	15 Pounds
SKU #	57325	OC Voltage:		Dimensions:	36.5" x 27" x 1.4"
Brand:	Thunderbolt	Max current:	6.2 Amps		

Modifications

Removing Corrosive Flux

Old power wiring needs to be replaced with longer, heavier gauge wire with Anderson PP connector)

<u>Quantity</u>	<u>Distributor</u>	<u>Part #</u>	<u>Description</u>
20 Feet	Powerwerx	Wire-RB-xxx	12 ga. Red/Black Zip Cord
20 Feet	Generic		3/8" Split Loom
1 ea.	Powerwerx	WP-30-xx	30 Amp Anderson PP Connector set
2 ea.	Fastenal	072 8339	6" narrow tie wrap.

Instructions

- Carefully pry open the junction box cover on the back of the panel.
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3. Clean off the corrosive flux (brownish/yellowish goo possibly with green corrosion) off the wire/lug junction with alcohol.
4. Unsolder the old wire and pull it out.
5. Separate about 6" of the red and black wires at one end of the 20' piece.
6. Slide the red and black ends into the junction box.
7. Strip back about ¼" from both leads.
8. Solder the red wire to the positive (+) lug.
9. Solder the black wire to the minus (-) lug.
10. Slide the 20" of split loom over the zip cord.
11. Tighten a 6" tie wrap near each end of the split loom.
12. Clip off the tie wraps as close to the body as possible.
13. Split the remaining end of the 20' zip cord about 1".
14. Strip back the wire approx. 5/16".
15. Crimp on the 30 Amp APP contacts with the APP crimp tool.
16. Insert the contacts into the APP plastic housing.

4:1 Solar Panel Combiner

- The 4:1 combiner allows you to add up to 4 solar panels. Use two of them to add up to seven panels (you have room for eight panels, but that's too much for the Victron 100/50 or any other 50 Amp MPPT controller).
- The panel side has four 30 Amp APP connectors, so panels can easily be plugged and unplugged at will.
- The wire leading to the controller from each combiner should be 10 gauge red/black zip cord (GFT ambassadors have used 12-gauge wire in 2022, when resources were limited, and it worked OK).
- Strip back the controller end wiring about ½" and tinning it with solder (unsoldered ends tend to fray).

<u>Quantity</u>	<u>Distributor</u>	<u>Part #</u>	<u>Description</u>
1 ea.	Blue Seas Systems	2508	8 circuit, 30 Amp Terminal Block
6 ea.	Blue Seas Systems	9217	30 Amp Terminal Block Jumper
8 ea.	Fastenal		10-12 Nylon fork terminal
1 feet	Powerwerx	Wire-RB-12-xx	12" Red/Black Zip Cord, 12 Ga.
1 feet	Powerwerx	Wire-RB-12-xx	12" Red/Black Zip Cord
1 feet	Powerwerx	Wire-RB-12-xx	12" Red/Black Zip Cord
1 feet	Powerwerx	Wire-RB-12-xx	12" Red/Black Zip Cord
3 feet	Powerwerx	Wire-RB-10-xx	3' Red/Black Zip Cord, 10 Ga.
4 ea.	Powerwerx	WP-30-xx	30 Amp Anderson PP Connector set

Solar Controller (Victron 100/50)

The Victron input from the solar panel accepts one or two 10-gauge zip cords with tinned ends. The battery output should be a run of 8-gauge zip cord, with the controller end tinned, and a pair of 8 gauge, 3/8" ring terminals at the battery end. 10-gauge wire is rated at 30 Amps, 8-gauge wire is rated at 55 Amps.

<u>Quantity</u>	<u>Distributor</u>	<u>Part #</u>	<u>Description</u>
6 feet	Powerwerx	Wire-RB-8-xx	8 Gauge Red/Black Zip Cord
2 ea.	Fastenal		8 Gauge ring terminal, 3/8" hole.

Battery Straps: 6 and 2 Gauge

In 2022, GFT Ambassador, Tom Herman, used both 6- and 2-gauge battery straps. The only time the #6 wire got even slightly warm was when the team pulled substantial current close to 1000 watts (80+ Amps). This is a case where practicality says 6 gauge works, but National Electrical Code (NEC) says no, and Tom should have used 2-gauge wire (95-130 Amps, depending on temperature). Again, you use what you have, and with the very small runs we had, it worked out just fine for Tom's team. GFT Ambassadors have built a bunch of #2 cables, and the #6 will do fine in smaller systems or as backups when or if you run out of #2's.

Battery Cable, 6 Gauge

<u>Quantity</u>	<u>Distributor</u>	<u>Part #</u>	<u>Description</u>
4 ea.	Powerwerx	Wire-WC-06-02-xx	6 Gauge Red Welding Cable
4 ea.	Powerwerx	Wire-WC-08-00-xx	6 Gauge Black Welding Cable
16 ea.	Powerwerx	Lug-06-3/8	6 Gauge Ring Terminal, 3/8" hole
5 ea.	Fastenal	0714597	1/2" Red Glue Lined Heat Shrink.
8 ea.	Fastenal	0710603	1/2" Black Glue Lined Heat Shrink.

Battery Cable, 2 Gauge

<u>Quantity</u>	<u>Distributor</u>	<u>Part #</u>	<u>Description</u>
4 ea.	Powerwerx	Wire-WC-06-02-xx	2 Gauge Red Welding Cable
4 ea.	Powerwerx	Wire-WC-08-00-xx	2 Gauge Black Welding Cable
16 ea.	Powerwerx	Lug-02-3/8	2 Gauge Ring Terminal, 3/8" hole.
5 ea.	Fastenal		1/2" Red Glue Lined Heat Shrink.
8 ea.	Fastenal		1/2" Black Glue Lined Heat Shrink.

Voltage Drop (right sizing and its importance)

Controlling voltage drop due to current. We have already talked about the importance of distributing generated power as high voltage AC; this is done for convenience and for minimal resistance losses in wiring and cords.

Let's discuss DC losses from the solar panel or panels all the way to the inverter. There are several different points in this, with some being less critical, and others where current drops in wire will absolutely destroy performance in

charging and the ability to supply the inverter. The least critical part of the system is the run from the solar panel or panels to the controller.

Typical solar panels run at a low current, 8 Amps or under. Open circuit (no load) voltages for “12 Volt” panels can be 20+ Volts. Panels operating at the maximum power point will put out somewhere in the range of 17-18 Volts. The controller will see slightly less voltage, but there is still plenty (under good sunlight!) to properly charge the battery and run the electronics.

Real World Case

A 20-foot run of #12 wire from an HFT 57325 panel (modified; original wire was 16 gauge and much shorter) to a controller.

Assume 5 Amps current delivered. The resistance of 40 feet (remember there is a (+) and a (-) lead, so that's 2 x 20 feet) of #12 wire is 0.06 Ohms.

With a 5 Amp current generated, the voltage loss is 0.3 Volts. It's a 1.5 watt power loss, but there is still plenty of voltage for the controller to use.

Solar Controller

Bargain basement and lower cost controllers don't take the voltage drop in wiring from the controller to the battery into consideration. If the controller is delivering, say, 14.2 Volts to the battery, but there is a 0.4 Volt drop in the wiring, a Lead Acid battery may still charge at 13.8 Volts, but a LiFePO4 battery certainly won't.

Better controllers have the option of a voltage sensor at the battery, which adjusts the controller output to compensate for wiring losses.

The losses for a single panel system are a lot less than that of a larger system that combines panels (power loss goes up by the square of the current, so a 10 Amp current flowing through a wire has 100 times the resistance loss of a 1 Amp current running through the same wire).

Let's assume a 5 Amp current typical of a single panel flowing through a 5-foot-long piece of #12 zip cord (2 x 5 feet, or 10 feet total): The resistance is 0.015 Ohms, and the voltage drop through that at 5 Amps is 0.075 Volts, which is less than 0.1 Volts. That most likely won't cause any real issues.

Now, let's say we have a combiner and several panels in operation, and we're near capacity; we still have the same 0.015 Ohms resistance, but with 45 Amps, we now have a 0.675 Volt drop between the controller and the battery or batteries. ***This is HUGE: with either a Lead Acid or LiFePO4 battery, you're simply not going to charge right.***

With 10-gauge wire (0.009434 Ohms), the drop is 0.42 Volts.

With 8-gauge wire (0.005933 Ohms), the drop is 0.27 Volts.

With 6-gauge wire (0.003731 Ohms), the drop is 0.17 Volts.

With 4-gauge wire (0.002347 Ohms), the drop is 0.11 Volts.

With 2-gauge wire (0.001476 Ohms), the drop is 0.067 Volts.

Clearly, the selection of the proper sized wire in a high current, critical application (charging the battery) is very important, especially if you have no way to compensate for the loss. Even if you could compensate, loss is still loss. Let's say you use 10-gauge wire (0.42 Volt drop) instead of 2-gauge wire (0.067 Volt drop). You would have a 0.353 Volt loss over using #2, and the power lost due to heating the wire would be almost 16 watts. That's power that is not charging the battery or being used.

Multiple Battery Systems

We need to consider how to size the battery straps used for connecting batteries together in parallel (this also applies to batteries or cells used in series). 7 inches is a good length for battery straps: They are long enough to connect the batteries together and give a little extra slack in case it's needed.

The location of the leads from the controller and going to the inverter is important: they should always be centered. Avoid hooking up to either end of the batteries (it doesn't matter in a two-battery setup). For a three-battery system, hook up to the center battery. For a four-battery system, hook up to one of the inside batteries. For a five-battery system, hook up to the one in the middle. For a larger system, follow the logic of the smaller ones.

Strap Sizing

Let's say we have a two-battery system, and the inverter is pulling 100 Amps (we have a good sized normal load, and we're brewing coffee on top of that, a real life situation): We want to pull an equal load of 50 Amps from each battery. If a strap is too small, one battery will deliver more current than the other one will.

Let's look at drops in 7" straps in various sizes, at 50 Amps:

With 10-gauge wire (0.0011 Ohms), the drop is 0.055 Volts.

With 8-gauge wire (0.00099 Ohms), the drop is 0.049 Volts.

With 6-gauge wire (0.00062 Ohms), the drop is 0.031 Volts.

With 4-gauge wire (0.00039 Ohms), the drop is 0.0196 Volts.

With 2-gauge wire (0.000246 Ohms), the drop is 0.0123 Volts.

Battery to Inverter

The last thing to consider is the leads going from the battery to the inverter. These are probably more critical than even the controller to the battery run, as potentially huge currents (100 Amps or more) will inevitably be called to flow through them, and the runs are long (2 x 4 feet). 8 feet of #4 wire (typically factory supplied with the larger inverters) has a resistance of 0.00188 Ohms. With a 100 Amp draw, that amounts to a 0.188 Volt wiring drop.