Field Guide – Setting Up a Basic Solar System

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

In this Field Guide…

Learn to set up a solar system in the field from the experience of Tom Herman, a Greening Fire Team Ambassador from Washington's Department of Natural Resources.

Bill of Materials:

Item	Description
1	100 W Solar Panel, HF # 57325, modified, w/20' cord & APP Connectors
2	Solar Controller, MPPT, generic, 12 or 12/24 Volts, 10 Amp.
3	Battery, Lead Acid, Marine Type, 12 V 80-105 AH
4	Inverter, generic, True Sine Wave, 300-400 watt, 12 VDC to 115 VAC 60 Hz
5	Power Monitor, Kill-A Watt, # P4400

- Setting up a basic, one Lead-Acid battery system with a generic controller and a single 100-watt solar panel.
- The four major components of a basic system (Kill-A-Watt not pictured).
- Inverter and Kill-A-Watt not needed if you are only running items that use 12 VDC.
- If you substitute a LiFePO4 battery, use a controller that specifically charges it!

Figure 1 A basic 4-major component solar system.

Instructions for Siting a Solar System

Figure 2 Solar panels set up at an angle with unobstructed sunlight.

1. Choose a convenient site close enough to where you are that gives you as much unobstructed sunlight as possible.
    - The best sunlight is from mid-morning to late afternoon.
    - Any shading on a panel can drastically reduce or stop its output current.
2. Set up the solar panels
    - Set up the panels at an angle so that the sun shines face to them. Flat on the ground works but reduces the amount of power generated.
    - If you can, move the panels every 3 or so hours to face the sun.
    - If you can't move the panels, set them up to get the best amount of sunlight that you can.
3. Set up the batteries
    - Site the batteries near the solar panels, but not so that they shade the panels.
    - Check the battery terminals for corrosion (Figures 15-17). If there is ANY, use metal bristle brush, terminal cleaner, or sandpaper to remove it. Corrosion is your enemy, doubly so if you need a lot of current to power a large load!
    - If using only one battery, skip to Step 4.
    - You want a reasonably charged battery (over 12.2 Volts for Lead/Acid, 13.4 Volts minimum for LiFePO4). The battery in the *Figure 3* is essentially a fully charged battery.
    - Connect the batteries together with the battery straps: OBSERVE POLARITY! Make SURE you ONLY connect like terminals together (+ to + and – to –).
    - Check battery voltage before you connect up:
        - You want a reasonably charged battery (over 12.2 Volts for Lead/Acid, 13.4 Volts minimum for LiFePO4). The battery in the picture is essentially a fully charged battery!
        - If you have low voltage, use a more fully charged battery unless this is all you have. It's also a good idea that if you use multiple batteries, that the voltages are close to each other. You don't want to connect fully charged batteries to exhausted ones (like in the next picture), unless you have no choice.
    - *Figure 4* is NOT what you want to see! At 10.65 Volts, this battery is fully discharged. It didn't recover after being charged. Subsequent testing showed it had no capacity and is junk.
    - A good but discharged battery will take a long time to charge fully, but a bad battery will jump quickly from low voltage to full regulated voltage and drop quickly again with a load put on it.

Figure 3 A fully charged battery.

Figure 4 A battery that is fully discharged.

4. Set up the solar controller and inverter (Connect to battery FIRST!)

- Verify that the controller you have is compatible with the batteries:
    - Same voltage and battery chemistry
    - Has enough current rating to handle the current from the number of panels hooked up.
    - Ensure the inverter is the same input voltage as your battery.
- Connect the controller to the batteries FIRST. DO NOT connect to the solar panels until AFTER the batteries have been connected!
- For a one battery system, connect the controller "-" lead to the battery "-" terminal, and the controller "+" lead to the battery "+" terminal.
- For a two-battery system, connect the controller "-" lead to one of the battery "-" terminals, and the controller "+" lead to the same battery "+" terminal.
- For larger battery systems:
    - Connect the controller leads as close to the center of the battery stack as possible.
    - You will later connect the inverter lead to the same spot.

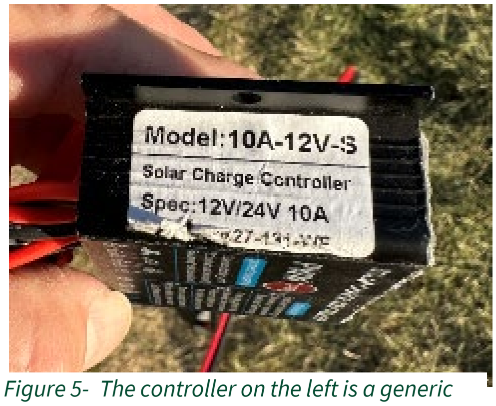

Figure 5- The controller on the left is a generic 12- or 24-Volt automatic unit capable of 10 Amps, with an SLA battery. It's waterproof and simple and will handle a single solar panel. It will regulate a 12 Volt SLA to about 13.5-13.6 Volts. This was an eBay purchase, about $12 delivered.

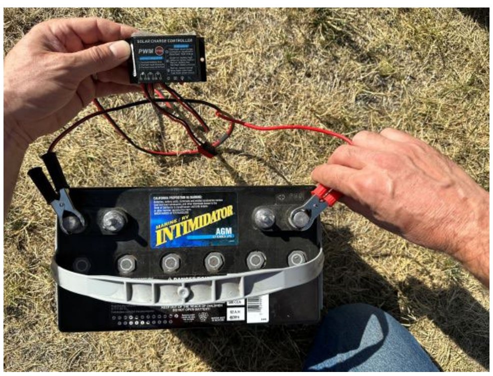

Figure 6 Controller being attached to the battery.

This is the generic controller being attached to the battery with clip leads. They work fine for low current work, but if you are going to draw significant current (such as with a heavy charging current or pulling a large load on an inverter), you'll want to use ring terminals for better connections.

Figure 7 Battery with controller and inverter.

This is the battery with both the solar controller and a small generic inverter clipped on.

5. Connect the solar panel(s)

- If you have one solar panel, connect it directly to the controller.
- If you have more than one panel, connect your combiners to the controller.
- Connect your solar panels to the combiners one at a time.

Figure 8 Solar panel connection to the controller.

6. Hook into the inverter

- Plug a Kill-A-Watt P3 4400 power monitor into the inverter output:
  - Use it as a Voltmeter to measure AC Voltage. A good range is up to 125 Volts no load, and as low as 110 VAC full load.
  - You can also use the Kill-A-Watt as a frequency meter, to measure current drawn, as a real time wattmeter (as shown here), and as a KWH meter to track total power consumed.
  - For less than $30, the P-4400 is a bargain for all that it does!
- Plug either an outlet strip or heavy-duty extension cord into the Kill-A-Watt to distribute power.

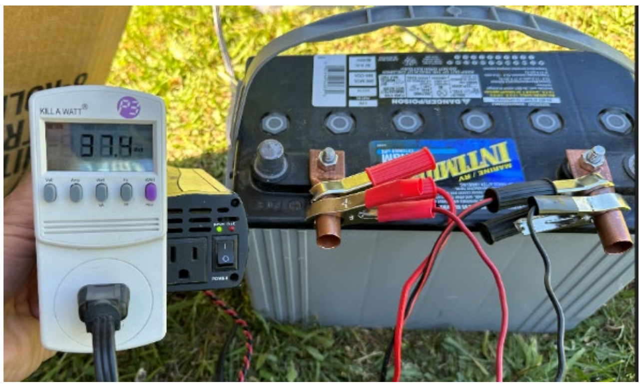

Figure 9 A battery hooked up to controller and inverter, being read by a voltmeter.

This is a setup using alligator clips and optional terminal extenders with both the solar controller and low power inverter (ca. 400 watts). It's shown delivering 37.4 watts to a soldering iron. That's just a little more than a CPAP machine uses with the heater tube turned on in cold weather.

Figure 12 This is reading the real time power delivered to the coffee pot: 785 Watts (112.6 Volts times 6.98 Amps).

Figure 11 Plug either an outlet strip or heavy -duty extension cord into the Kill-A-Watt to distribute power (6.98 Amps AC to power the coffee pot).

Figure 10 Here's the inverter output voltage (112.6 VAC) with a 1500 watt rated unit delivering 800 watts to a coffee pot (about 70 Amps). This is on the low end of the output voltage, but there is quite a bit of sag due to the high current voltage drop in the DC cables going to the inverter (3 SLAs in parallel for 12 Volts at roughly 300 AH capacity).

7. Test the System, DC side (AC already mentioned above)
   - Check the batteries for voltage.
     - If they are short of full voltage (13.5-14.2 V for Lead Acid, 14.4 for LiFePO4), you should see the voltage rise slowly if the panels have good sunlight and the controller is working.
   - Recheck the batteries periodically to verify that the controller cuts off charging voltage at the right point:
     - 13.4-14.2 V for Lead Acid, 14.4-14.6 V for LiFePO.
     - If the batteries go higher than this, the controller may be defective.
     - Lead acid batteries will gas above 14.4 V and the BMS in LiFePO4 batteries will disconnect them above 14.6 V.

Figure 13 Fully charged battery.

At 12.73 Volts, this battery (on left) is essentially fully charged. It's a perfect candidate to be put into service, either by itself or together with several other similar high charge state batteries.

This battery (on right) is sitting fully charged at 13.56 Volts. This is the high voltage set point for the regulator in this generic controller.

Figure 14 A battery not fully charged.

Note 1: The "basic" will produce at least 400-watt hours (0.4 kWH) per day in good sunlight, and significantly more during the height of summer.

Note 2: The "basic" can safely power 2-3 CPAP machines in full sunlight, warm weather, and 2 CPAP machines in cold weather (heater tubes on). Power draw approximately 0.15 kWH warm, 0.2 kWH cold per unit.

Note 3: Example Battery Terminals

Figure 15 A battery terminal with corrosion.

Figure 16 A battery being cleaned of corrosion with a metal bristle brush.

Figure 17 A clean battery terminal without corrosion.