Installing a Small, 12 volt, Off-Grid Solar System 2009

Disclaimers: Information for a safe solar system is presented here. Do not substitute materials. I cannot take responsibility for creative ways you may decide to screw up.

This installation will not meet national electric code standards. If you must build to code, hang on to your wallet, and may God be with you.

Sources: The following ideas are from…

- *Low-Voltage Wiring* by Tom Moates, *Back Home Magazine*, September/October 2003, pp. 20-23.
- *Installing Your Own Small, Remote Off-Grid Solar System* by Jeffrey R. Yago*, Backwoods Home Magazine*, March/April 2009, pp. 35-40.
- and from 35 years of personal experience.

Why have a 12-volt system?

A. Cost. It is much less expensive. Inverters can cost thousands of dollars.

B. Simplicity. With a few components, your system is complete.

C. Efficiency. A 12-volt system is more efficient. For example, a single light bulb using AC pulled from an inverter can draw at least twice the battery current as a DC bulb drawing directly from the batteries.

D. Safety. A 12-volt system can be safer. It is difficult to electrocute yourself with 12 volts!

What is a "small" system?

In this case, a system with up to 400 watts of 12-volt photovoltaic panels.

Panel to Battery Ratios

Assuming that you will have at least five hours of bright sun on most days, it would be ideal to have 200 watts of panels to charge each battery, assuming the batteries are the ones suggested in these plans.

(One battery will store about 1 KWH of electricity when discharged to 50%)

You can use fewer panels per battery to start your system and work toward an ideal system as your budget allows. If you live in a cloudy place, you may need more panels per battery.

To keep your budget within reason, you can experiment with your battery to panel ratio. How you use your system will determine how many panels and batteries you need. I have 400 watts of panels and a 400 watt wind generator charging ten batteries. In sunny Colorado, this has worked well. I also use a generator and a battery charger about five or six times a year to assist my panels and windcharger on grey, windless days.

How Much Electricity Will a Small 12 VDC System Provide?

If you are careful to turn off lights and other appliances when they are not being used, you should be able to operate 4 or 5 LED or CFL lights, a 12-volt RV water pump, a small fan and a laptop computer. When the sun is shining brightly, you can use your system for a variety of other tasks: pumping water for the garden, powering electric tools, etc.

What Kind of Batteries Should I Use?

For the sake of simplicity, I suggest a sealed, gel, deep-cell battery. DEKA brand batteries have an excellent reputation for durability. If you buy cheap batteries, you will have to replace them more often. Never use auto batteries. They are not designed for this purpose and will be a waste of money.

Sealed batteries are maintenance-free and leak proof. The most important feature is that these batteries do not have to be vented. Unlike sealed gel batteries, lead acid batteries must be refilled from time to time with distilled water and must be vented to the outside because they create explosive hydrogen gas when being charged or discharged. While sealed gel

batteries cost 40% more than comparable lead acid batteries, I believe they make sense for the beginning solar electric user or the person who does not want to worry about their batteries.

Note: Your charge controller must have a setting for gel batteries to prevent battery damage.

Note: Batteries are heavy! Make sure you will be able to move them and that your structure will support them. I purchase batteries that weight about 70 pounds. Most people can handle 70 pounds. You may want heavier batteries to make theft difficult.

Note: Batteries operate best at temperatures between 50°- 90°F. For this reason and to discourage theft, I put my batteries inside my living space.

For this small system, I am going to start with one 85 watt 12-volt Kyocera photovoltaic panel ($500) and one 12-volt, DEKA, gel cell battery, model #8G31 ($200).

What About a Refrigerator?

A very small system (200 watts of panels and one or two batteries) will not produce enough power for even the most efficient (and expensive, $900-$1500) refrigerators and freezers. With 400 watts of panels and four batteries, you may sometimes run a bit short of power. You may want to look at small Sun Danzer freezer. You can make ice and place it in an ice chest. You will get maximum performance for minimum dollars in this way. Others options for refrigeration are propane and kerosene refrigerators and freezers. I have a Danby propane refrigerator/freezer ($1000) that has given me excellent service. Still, if I had the money, I would invest in the extra solar for a Sun Danzer refrigerator/freezer. Propane is expensive and still going up!

The Charge Controller

The charge controller is the brain of your system. It protects your batteries from over-charging and over-discharging. I recommend the Morningstar PS series because of their price, features and dependability. Two features

are particularly helpful. A built-in battery disconnect allows you to isolate the battery bank for safety or maintenance. The other great feature is the metering. I always put the charge controller where I can easily see the meters. With a digital LCD display, the Morningstar tells me the voltage of my batteries, the amount of amps coming from my panels and the amount of amps that I am using. The controller has LED lights that warn me of any problems. It also has a switch for sealed batteries.

Wire Sizing for a 12-VDC System

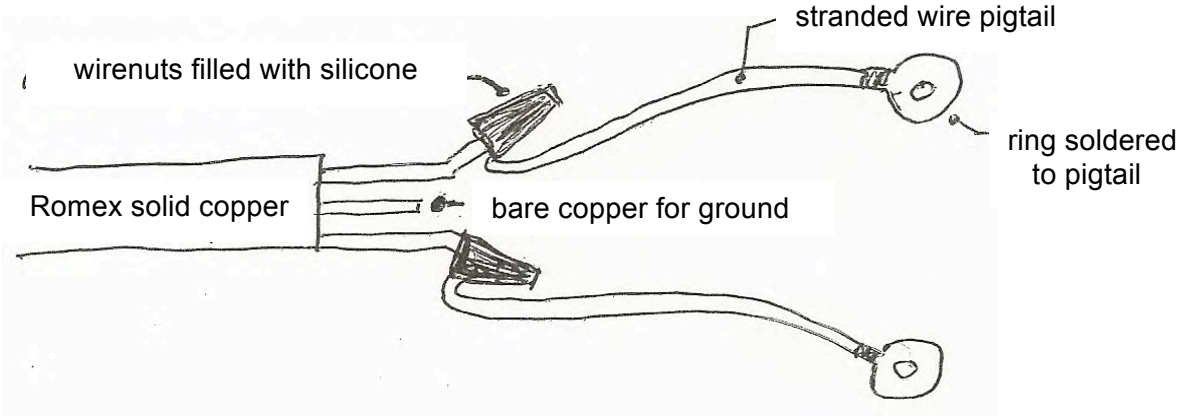
12 VDC needs heavier wiring than 120 VAC. Using copper wiring (no aluminum) at lengths of 50 feet or less, use the following chart:

LOAD	AC Sizing	DC Sizing
10 amps	#14	#14
15 amps	#14	#12
20 amps	#12	#10
30 amps	#10	#8
60 amps	#6	#4
100 amps	#2	#1

If your wire run is longer than 50 feet, go to the next larger size of wire. Keep all wire runs as short as possible. Put panels and battery banks as close together as possible.

Wire Connections

To attach heavy wire to switches, receptacles and fuse boxes, ring terminals and blade-type connectors, available at good automotive parts stores, should be soldered to wire ends. Do not just clamp on connectors. Often I add a pigtail of stranded wire to the end of my solid wire because it is more flexible and easier to manipulate.



Note: Solder – there are two types of solder typically available, one for electrical use and one for plumbing. Use electrical, rosin-core solder.

Corrosion

After wires are attached, all bare connections should be treated with a corrosion preventative, available at an auto parts store. A product called NO-CO NCP_2 works well. Vaseline or bearing grease or silicone will also work. Silicone is permanent. Do not put it on any screws or bolts that may need to be tightened or removed at some future time.

Receptacles

Do not use standard AC receptacles for a 12-volt system. If you plug a 120-volt AC appliance into a standard receptacle wired for 12 VDC, you will ruin your appliance. You can use a 20-amp, 250-volt receptacle. The receptacle pattern design should be different from a standard 120-volt AC receptacle so that it is physically impossible to ruin AC appliances.

I use 12-volt cigarette lighter receptacles because it is simple. Most 12 VDC appliances have a cigarette lighter-type plug.

Switches

You can use 12 VDC switches that you can buy at any auto parts store. You will often read that standard AC switches will not work in a 12 VDC system. My friend, Les Eldeen, who has installed more than 8000 solar systems, informs me that he uses standard switches in his systems with no problems. You can avoid the switch issue and simplify your wiring by purchasing 12 VDC light fixtures with built-in switches, available at RV dealers.

Breakers and Fuses

If you like breakers, the Square D "QO" line of AC breakers will work for 12 VDC. This only applies to the "QO" line by Square D.

I use ATC blade-type automobile fuses because of cost and availability.

Every circuit should be fused. This helps prevent fires and protects appliances. Include a fuse in the positive wire between the solar panels and charge controller, and between the charge controller and the battery.

System Grounding

Proper grounding will help prevent lightning damage. Every solar module has a predrilled and labeled hole in the frame for a ground wire. Use #10 bare-copper wire to connect to each module. Then run the wire to a copper clad ½ -inch steel ground rod driven next to your home's foundation. Wherever a connection is made, use a corrosion preventative.

Each receptacle or switch need not be grounded using the bare copper wire in standard romex cable. **This applies only to 12 VDC systems.** Romex cable is the type of highly insulated wire that is typically seen in house wiring.

Installing Photovoltaic Panels

Note: When installing panels, cover them with a tarp to avoid sparks and electric surges during installation.

Panels must face the sun directly (usually south) and must not be shaded in any way. Even just a little shading will dramatically decrease panel output. The panels can be mounted on your roof or on a pole. In areas where theft is a problem, panels can be welded on a 15-foot metal pole placed in lots of concrete.

Solar panels produce the best year-round performance with a tilt angle equal to your latitude. For most of the United States, this is from 37-42 degrees. A lesser angle will improve summer output, and a steeper angle will be better in winter.

Make sure the panels are securely mounted so that they cannot be blown away by the wind. Wind-lift is a problem. Use stainless steel screws or lag bolts that are anchored into studs, not just plywood sheeting.

Wiring Your System

Safety Note: You must avoid “crossing your wires”, that is attaching positive wires to negative posts or vice versa. Use black for positive and white for negative. For this small 12 VDC system, the bare copper ground in romex wire need not be used at each appliance. Ground the system as shown on the diagram. Plus and minus are clearly marked on the panels, the charge controller and the batteries. PAY ATTENTION!

Safety Note: Do not connect batteries until all other connections are made and tested.

The 12-volt panels should be wired in parallel, that is plus to plus and minus to minus.

If you have more than one panel, you should use a combiner box located close to the panels. Notice that each panel runs directly to the combiner box. Use copper wire, type “use 2” or equivalent. This wire is high temp,

sunlight and waterproof. Because the ultraviolet rays can be so damaging, I run any wire exposed to the sun in an old piece of garden hose.

Follow the diagram carefully, noting wire types and sizes.

Connect the wires from the panels to the charge controller. Be sure to include a 30 amp fuse on the plus (+) side between panels and the charge controller. Run wires from the charge controller to your batteries but do not connect them yet. Be sure to include a 30 amp fuse on the plus (+) side between the charge controller and the battery. Run wires from the charge controller to the fuse box or breaker box. Run wires to individual lights and receptacles.

Double check every connection for shorts (i.e., plus being connected to minus.)

Carefully connect your batteries. Carefully touch the wires coming off of the batteries. They may become slightly warm, but not hot. If they are hot, disconnect them immediately. If your fuses blow, disconnect the batteries immediately. Check again for shorts. Black wires to positive, white wires to negative. Reconnect your batteries and check them again.

After you have the batteries connected and working without overheating, check each circuit for proper fuse size as follows:

Turn on every light or appliance typically used in the circuit. Start with small amp fuses. If they are too small, they will blow quickly. Try the next size higher amp fuse. A fuse that is too heavy for the circuit can cause fire or damage to appliances before it blows. A fuse that is too small will blow often. You are Goldilocks looking for the fuse that is “just right’.

Finally, make a chart that shows what appliances are on each circuit and what size fuse is required. Keep the chart close to your fuse box. Example:

Fuse #1.....water pump .....9 amps
Fuse #2.....bedroom lights.....30 amps
Fuse #3.....receptacle by kitchen sink...20 amps

ENJOY YOUR ELECTRICITY!