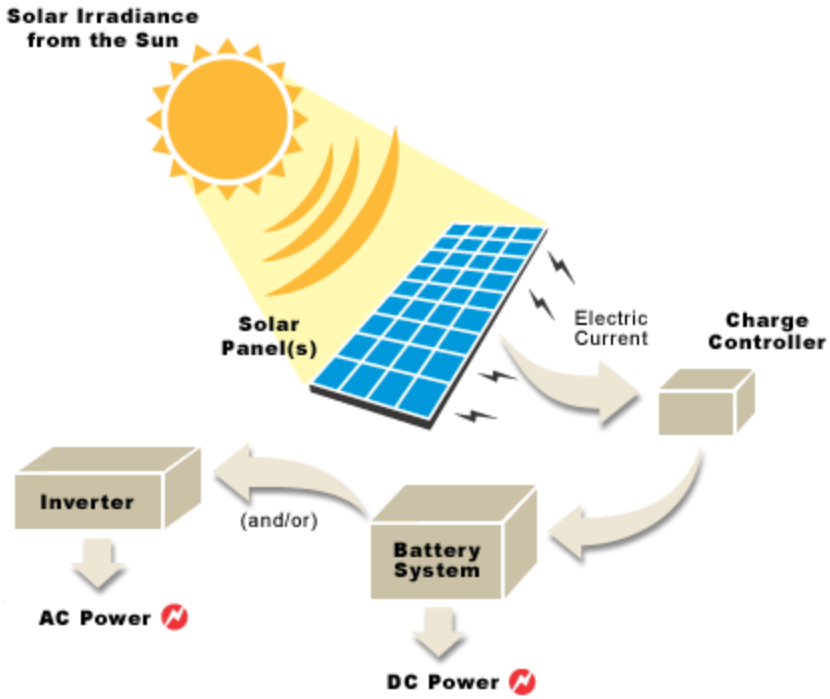
The Van Dwellers Guide to Solar Electricity

or

How to avoid external power connections and generators

by Steve Spence



Living a mobile lifestyle brings some unique challenges to living on solar generated electricity. Although the basic system is similar to a larger home system, the environment demands design changes regarding how we mount the solar panels, battery selection, and more.

In this article I'll show you how to untether from the grid, and avoid a smelly, noisy, fuel consuming generator except in extreme weather conditions. Keep in mind, this system can outlive several vehicles, so it should be considered a capital expense, like your vehicle itself. It can be pricey for a good system, but you'll have minimal ongoing expenses, unlike fuel and maintenance on a generator.

A photo-voltaic (PV) system consists of panels that convert sunlight into electricity, a charge controller to prevent the batteries from overcharging, a set of batteries to store the electricity for when the sun is not shining, and often, a inverter to turn the low voltage DC (battery voltage) into normal 120 volts AC house current.

Solar Panels (PV)

There are two ways to mount solar panels in a mobile environment. Fixed, on the vehicle itself, or a removable, portable mount that can be setup some distance from the vehicle. Mounting your panels flat on the roof, or attached to a roof rack, makes sense from a security, stealth and convenience standpoint, but lowers your collection ability, and requires you to park in the sun, which in hot weather, will increase your cooling needs. Roof space is limited, so you want the most efficient panels you can afford to maximize collection.

Having a portable mount that you can set up away from the vehicle, lets you aim the panels for better collection, and keep your vehicle hidden from view or out of the sun (if necessary), but could encourage theft. I'd suggest an alarm circuit on the panels (tied into the vehicle alarm system) to notify you if they are disconnected without your knowledge. As you are not limited by the roof space available, you can have more panels, limited only by the storage space in or on your vehicle when traveling.

The size of a 200 watt panel is approximately 60" x 40" x 1.5", and weighs about 40 lbs, so keep that in mind when thinking about mounting methods and location.

Charge Controller

The solar panels are wired to an on-board charge controller. This unit makes sure that the batteries get fed the proper amount of electricity, at a rate they can handle, and will help ensure longer life from the batteries. The traditional method is to have a 12v solar panel, a 12v charge controller, and a 12v battery. The newer and more efficient method is a series string of panels running at a higher voltage (100v or less, but at least 20v higher than battery voltage), a special MPPT controller, and the 12v battery pack. The MPPT controller matches the best performance cuRVe of the panels to the batteries, allowing up to a 30% increase in power, without needing more panels.

Batteries

The typical battery in an off grid system is a flooded lead acid battery. This unit has vented caps, discharges hydrogen during charging, and needs to be vented, as well as rewatered fairly often. A better solution for mobile use is the AGM battery. This unit does not need venting, and is sealed, eliminating watering. It also won't leak acid in the case of a roll over or physical damage. It is more expensive, so there is a trade off. Deep cycle (do not get starting batteries) come in 6v and 12v. Consider two 6v in series to be a 12v. You can parallel multiple 12v batteries (or 6v pairs) to increase Amp Hour storage (two 100ah batteries in parallel = 200ah). Batteries in series add voltage, batteries in parallel add amp hours.

Inverter

An inverter changes 12vdc into 120vac for regular household appliances. Usually, since vehicles (and RV's) are set up with 12v systems, a Inverter is a nice option, but not absolutely necessary. I've found that typically my AC needs are a microwave, and air conditioner, and a TV. Things like cell phones and laptop computers have 12vdc car chargers available, eliminating the need for the 120vac “wall wart” (the little black transformer that plugs into the wall. Found on everything from cell phones to answering machines). Inverters can range from the cheap $60 750 watt Black and Decker from Walmart, to a $2500 Xantrex or Outback with integrated battery charger and transfer switch for connecting to the grid or a generator.

Fuses, Breakers, and Disconnects

For safety, and convenience, we install fused disconnects between the solar panels and the charge controller, between the charge controller and the batteries, and between the batteries and the inverter. This allows us to safely isolate the components for maintenance (or panel deployment), or automatic disconnect in case of a short or equipment malfunction.

Battery Monitor

Running a system without a battery monitor is like using a bank account without a check register. You have no idea how much energy you have, till it runs out and you are in trouble. The simplest, and least effective is a volt meter. It will tell you the voltage of the battery pack, but that reading is highly affected by charging and discharging, making the reading basically useless. The best method is an amp hour meter on your battery pack, that indicates amp hours deposited, and amp hours withdrawn. These units commonly also include a amp and volt meter function. There are standalone units like the Bogart Trimetric, and integrated units like the Outback Flexnet DC. A standard multimeter ($15 at Radio Shack) is useful for detecting power, polarity, and continuity, but not as a system monitor.

Wire Size

Wire size is a function of amps being carried, and the distance they need to move. If you have 40 amps (480 watts) of PV on your roof, and it's 8' to the charge controller and batteries, then you should use 8 AWG wire between the PV panels and the charge controller (and from the charge controller to the batteries). The wires between your battery(s) and inverter should be short and large. A 2000 watt inverter, 6' from the battery bank, needs 1 AWG battery cables. The smaller the AWG, the larger the cable. If your cables are too small, they will generate heat, and possibly a fire, as well as dropping the voltage to less than useful levels. Use the calculator at the bottom of http://www.powerstream.com/Wire_Size.htm , and use 3% voltage drop (or lower) as your target.

Generators

I know I said we wanted to avoid these things, but sometimes you can't. If you are parked in direct sun in 100 degree weather, you are going to want an air conditioner, and that means a grid connection, or a generator. We like the small Honda EU series. They are small, quiet, and scalable (can run one for small loads, and slave a second for heavy loads). Yamaha makes a similar series. Both can be modified to run on gasoline and/or propane. This is where you'll want the better inverter/charger/transfer units as mentioned in the inverter section, as there just one wire to connect to the generator, and switching/charging is automatic.

Vehicle Charging

While you are driving a battery isolator will allow your vehicles alternator to keep your battery bank charged, without allowing your starting battery to be discharged by your appliances. Common at RV dealerships these can be solid state units, or a relay based unit. I prefer the relay based unit as it doesn't have the voltage loss the solid state units have, and is less expensive.

Sizing the system - Math Alert!

I'll try keep this simple.

A 200 watt panel, optimally aligned (solar south, at an angle similar to latitude with seasonal adjustments), might gather 600 watt hours daily in NY (3 full sun hours * 200w), or 1200 watt hours in CA (6 full sun hours * 200w). 1200 watt hours is enough energy to run a 100 watt light bulb for 12 hours. See the pattern? Fortunately, we have better options than a 100 watt light bulb. In our camper, we have installed 2.5 watt LED dome lights. As bright (and same color) as the typical RV 18 watt 921 bulb, it will last almost forever, won't burn out, discolor, generate heat, and uses so little power your batteries will hardly notice it's on.

Here are some basic formulas:

Volts * Amps = Watts
Watts * Hours = Watt Hours
Watt Hours / Volts = Amp Hours
Amp * Hours = Amp Hours

More at http://arduinotronics.blogspot.com/p/tutorials.html

A 200 watt panel that produces 12v (nominal, it actually produces 15-20v) might produce 200 w / 12 a = 16.7 amps. In 3 full sun hours (NY), it might produce 600 watt hours (3h * 16.7a = 50 amp hours. 50 amp hours * 12v = 600 watt hours).

A battery rated at 100ah has about 50ah usable (50% discharge) otherwise it's life could be severely degraded. Typically batteries are rated at the C/20 rate, so a 100ah battery might deliver 5 amps for 20 hours. Taking into effect the 50% discharge, you are looking at 5 amps for 10 hours. If you pull the amp hours out faster, you have fewer usable ah. If you pull it out slower, you have more usable ah.

More sizing info and a chart showing sun hours for various areas is found at http://www.green-trust.org/2003/pvsizing/default.htm

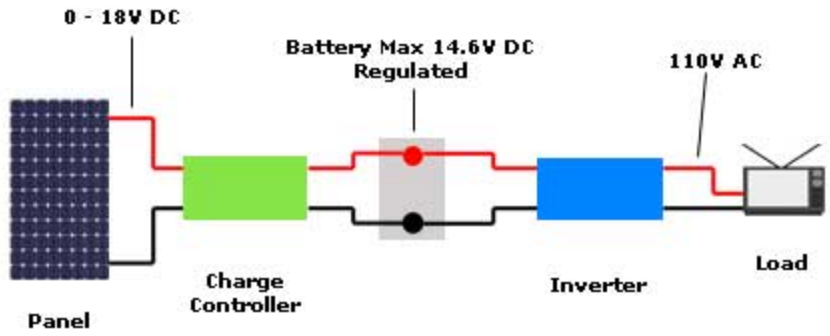
A calculator for battery and solar sizing can be found at http://www.green-trust.org/peukert/

More on "Loads" and "Run Times"

A 700 watt (cooking watts) microwave might pull 1000 watts. If used for 15 minutes, it consumes 250 watt hours. A 30 watt laptop computer used for 4 hours would consume 120 watt hours. Consider our 2.5 watt LED lights. If 6 are left on for 4 hours,
6 * 2.5w = 15w
15w * 4h = 30 watt hours.
30 watt hours / 12v = 2.5 ah.

A Kill-A-Watt meter is a useful meter for monitoring the amps, watts, and watt hour consumption of 120vac devices, and can be found for around $20 at Radio Shack, Amazon.com and other places. There are similar devices for measuring 12vdc loads.

Putting it all together



So, you have mounted the panels on the roof or on a portable rack. You'll want to connect them in parallel (unless using the MPPT controller (It's panel and controller specific, so check the data sheets for both), keeping array voltage below 100v is usually best) connecting positive to positive (red), negative to negative (black), and bring the wires inside to the charge controller (remember, series adds voltage, parallel adds amps). Don't forget your fused disconnect between the panels and the charge controller. If using a portable mount, you'll want a quick disconnect for "unplugging" the panels. Make sure your connection into the vehicle is water and chafe proof.

Next connect the charge controller to the batteries. Again, it's positive to positive (red), negative to negative (black), with a fused disconnect in between.

Next connect the batteries to the inverter. Again, it's positive to positive, negative to negative, with a fused disconnect in between. If installing the vehicle charging option, the isolator connects between the vehicle alternator and the new "house" battery pack.

What's it going to cost?

A basic low end system might consist of a 200 watt panel ($550), a 20 amp charge controller ($100), Two Walmart type 27 marine deep cycle 12v batteries ($160), and a Walmart 750 watt inverter ($60). With miscellaneous wire, fuses and connectors, you are looking at just under $1000 for an autonomous, gridless, no power bill, power system.

A higher end mobile setup might consist of 400 watts of PV ($1100), a 40 amp charge controller ($150), 200 ah of AGM battery storage ($500), and a 2000 watt inverter/charger ($1700). With miscellaneous wire, fuses and connectors, you are looking at just under $3600.

I'd recommend more battery storage if possible.

Steve Spence
sspence@green-trust.org
http://www.green-trust.org