Minimal Solar Backup

I consider a solar system one might use to live off grid in an RV to be the minimum most folks would want to live with. Such a system would only be able to power a few essentual items in most houses, but we lived in an RV for 4 yrs after we retired and the following system is what I'd recommend after learning several lessons the hard way. It's not exactly the system we have, but represents a cost effective design I wish we'd started with, rather than what we slowly evolved to via the school of hard knocks. Much of the information we learned along the way was care of Handy Bob Solar, who can be found on the web at http://handybobsolar.wordpress.com/.

The electrical diagram for this system is shown in Figure 1 and is composed of the components listed in

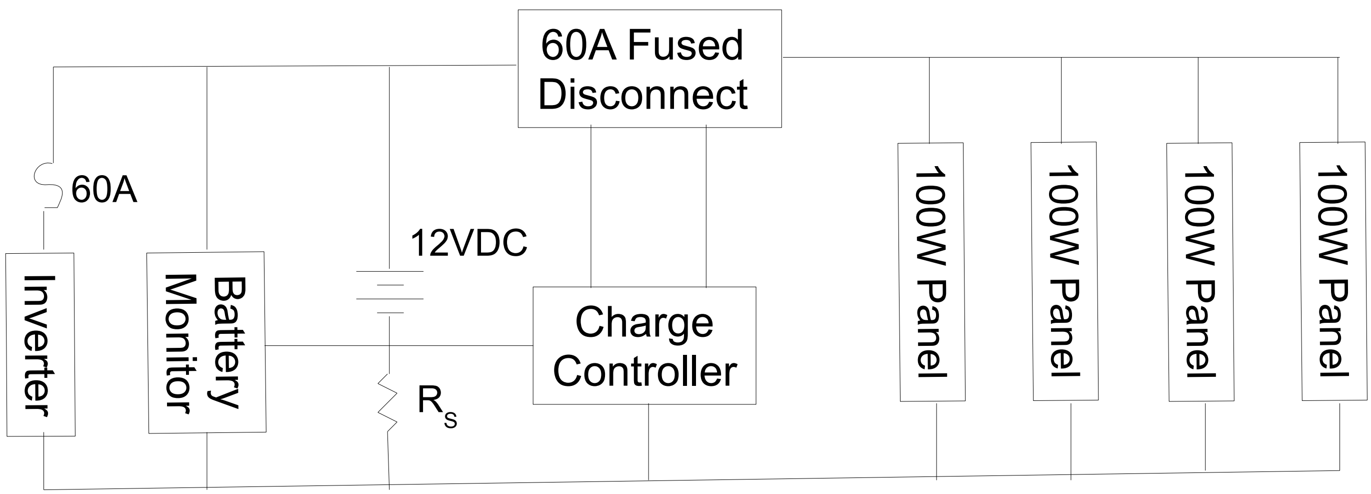


Table 1, which includes the approximate component costs as of 2015.

Figure 1. Solar System Electrical Diagram

Qty.	Component Description	Price
1	MorningStar SI-300-115V -UL SureSine 300W Inverter, 115V, 60Hz	$251
1	Morningstar TS-45 TriStar 45 Amp Charge Controller 12-48V PWM	$150
4	Windynation 100 Watt Polycrystalline 12V Solar Panel	$524
4	Trojan T-105 6V 225Ah Flooded Lead Acid GC2 Deep Cycle Battery	$600
1	Bogart Engineering Trimetric TM-2030-RV Battery Monitor System	$155
1	Bogart Engineering Deltec 500 amp, 50 millivolt current shunt	$27
1	Square D Pull-Out Disconnect Switch 60A Not Fusible - UFP222R	$26
	Approximate Total Component Cost	$1,733

Table 1. Recommended solar components, quantities and approximate cost

To understand how the system works, lets start with the 4 solar panels on the right side of the diagram. The way they are connected is pretty much dictated by the way the charge controller is designed and the battery voltage. The charge controller is of a PWM design, which stands for Pulse Width Modulation. That's a fancy way of saying the charge controller acts as an on/off switch for charging the batteries. When the battery voltage is low, it will be on most or all of the time. As the batteries become fully charged, the switch will be off most of the time only providing the power needed to keep the batteries in the fully charged or float condition. The 4 panels are each able to produce around 17-18VDC under no load condition, which is a good thing because more voltage might not be good for the batteries. They are connected in parallel with their positive terminal at the top of the diagram and negative terminal at the bottom, which acts as system ground. The positive lines are brought together in the disconnect which has two lines in and out. One side of the disconnect disconnects the solar panels from the charge controller while the other side disconnects the battery from the charge controller. This allows one to safely shut down battery charging for installation or maintainence. A fused disconnect provided additional protection, but I have to admit I'm currently using an unfused disconnect like the one listed in the table.

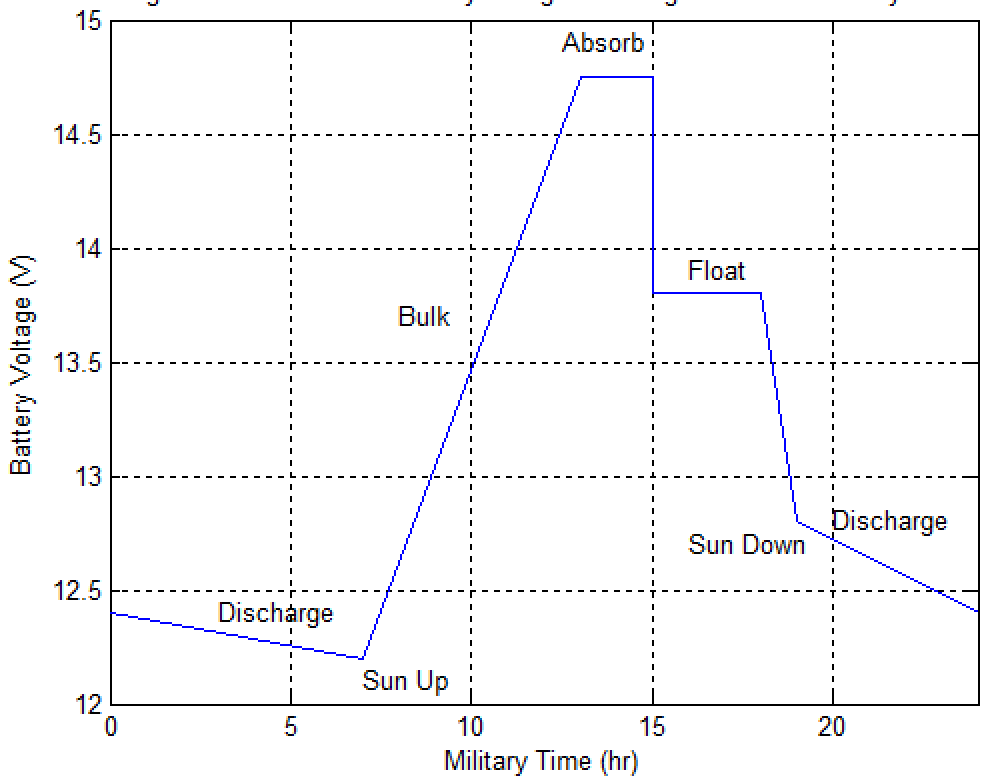
Battery charging is accomplished by current flowing out the left side of the disconnect into the battery, down through the shunt resistor, R_s and back into the solar panels. At first blush, putting a resistor in series with the battery might not sound like a very good idea. But the shunt resistor allows the charge controller and battery monitor to keep track of how much current is actually flowing through the battery. This allows them to determine the batteries current state of charge at all times in order to optimize battery charging. The shunt resistor is a very precise low resistance component, 0.0001Ω for those of a technical bent. Hence the charge controller and battery monitor has connections to both sides of the shunt resistor to measure the voltage drop across it. So the charge controller is basically acting as an on/off switch between the positve battery terminal and the positive solar panel terminal that uses battery voltage and current measurement to optimize battery charging.

The battery monitor is the human interface to the system telling one the battery voltage, battery current and percent of charge. Deep cycle batteries should **never** be discharged below 50% of their capacity if you want them to last a long time. So if your batteries are getting low, it might be a good idea to put your electic coffee pot away until they've been recharged. Many folks try to skimp on cost and not include a battery monitor. I can tell you from experience, this can be a costly mistake. Our RV system didn't have one initially and I wasn't able to tell that my batteries were being undercharged everyday and it only took me 2 yrs to kill a $600 set of batteries. But it actually turned out to be a blessing, as I met Handy Bob and put the system back together the way it should have been in the first place. That was in 2009 and it's still going strong today.

Inverters are connected to the positive battery terminal, through a 60A fuse which in this case is connected to the bottom of the shunt resistor. This allows the charge controller and battery monitor to keep track of the batteries current state of charge. The recommended inverter is a small 300W full sinewave invertor able to run a number of small loads. We used it 99% of the time to run our electronic gizmoses. However, if one intends to run large power devices like power tools, coffee makers or things in general requiring more than 300W a second high power invertor is required. Our RV has a 2000W inverter for this purpose that wasted an Amp or 2 just setting there doing nothing. The smaller inverer was an afterthough, but we could go for weeks without using the big one and wasting the Amps. It's also important to remember that inverters have a surge capability for starting thing that take a little extra power to get them going. The surge capability of the 300W inverter is 600W, for a short period of time, which is why the fuse protecting it is 60A. The fuse has to be able to handle the surge.

To get a feel for what the charge controller is doing over the period of a day, consider the notional floated lead acid battery voltage vs time curve shown in Figure 2. Time starts at midnight when the battery has already been discharging since sun down. The discharge continues until sun up when the solar panels once again start producing power. The charge controller attempts to recharge the battery as quickly as possible by routing all available power to the battery. This phase of the process is referred to as Bulk charging. As Bulk charging continues throughout the morning, the battery voltage slowly increases until the battery is roughly 100% charged. At this point the charge controller starts throttling back the power going into the battery by holding the voltage around 14.7-14.8V for floated lead acid batteries on a 70°F day. This stage is called Absorb and it's purpose is to slightly overcharge the battery. The Absorb phase helps insure all battery cells are fully charged and returns sulfites that have percipitated out of the solution back into solution. Absorb usually takes around 2 hrs, at which point the battery is fully charged and the charge controller drops the voltage to a level that allows the battery to remain fully charged. This is called the Float phase during which the charge controller attempts to supply all system power needs from the solar panels. It's no longer able to do this as the sun goes down and the battery once again starts discharging until sun up the next morning and the process starts all over.

Figure 2. Notional 24hr Battery Charge/Discharge Profile for 12V System



Now some folks may say they don't care about all this Bulk, Absorb and Float technical mumbo jumbo. They just want solar and will be glad to leave all that to the geeks. Well the unfortunate fact of the matter is when you install your system, the last step before flipping the switch on is that you'll be required to define for the controller what the Absorb and Float voltages you'd like it to use are. In addition, you'll also have to tell it how long to remain in Absorb among other things. So the manufacturer is assuming he sold his stuff to the geek and the geek will set it up properly. A word to the wise. Ya need to understand this if you're gonna do solar!