Managing a 12-volt solar system

Solar systems take little work to maintain. However, for better performance of the system, there are some chores that may be important. It is also important to stay within the limits of the system, or the batteries will die prematurely. This article focuses on simple management, using very simple tools, the way it has been done for decades.

The topics in this article include:

- maintaining the solar panels
- interpreting the voltages
- temperature compensation
- equalization
- adding distilled water
- cleaning the battery tops

There is also a small troubleshooting guide in the back. If you find the information in this article too technical, you may need to consider whether off-grid living is something you should do. Or, at least make sure you have someone local whom you can count on for ongoing help.

Introduction

People who live off the grid will need to manage the limited resources of their system. The limits are determined by the size of the solar panels, the size of the battery bank, the age of the batteries and the current weather.

The battery bank of a solar system is an investment of hundreds and sometimes thousands of dollars. A battery bank that is ignored may fail prematurely and need replacement. A battery has a certain amount of stored electricity. Using more than 50% of it is hard on the battery and should not be done often. This can be avoided by knowing how full the battery is and simply being mindful of how the system is doing at the moment.

There is fancy computerized equipment to help with this task, but these digital gadgets may be a problem for sensitive people.

This article assumes a very simple system, with no digital equipment. A system like those off-grid people lived with in the 1980s and 1990s. The only instruments they had were the voltmeter and the hydrometer.

We will assume here that flooded lead-acid batteries are used, as they are the most common types used in off-grid systems. They include standard automotive batteries, marine/RV batteries, golf cart batteries, traction batteries (L-16), forklift batteries, etc. Batteries that are not standard lead-acid include Advanced Glass Mat (AGM), gel-cell, sealed lead-acid, lithium, nickel-cadmium, nickel-ferro, etc. Their maintenance and management will be somewhat different than described here.

Lead-acid batteries do not have the memory-effect that is an issue for nickel-cadmium batteries, so there is never a need to fully deplete a lead-acid battery. Doing so would damage it.

Maintaining the solar panels

The solar panels are virtually maintenance free, if they are mounted on a sturdy rack and the wires are installed professionally (preferably using flexible conduit). There are a few small chores that can be undertaken to improve the performance of the system, however.

If the tilt of the solar panels is adjusted once in the spring and once in the fall, the sun will shine more directly down upon the panels and generate more electricity throughout the year. This is because the sun is lower on the sky during the winter, while it is much higher up in the summer.

The optimal tilt depends on the latitude. A good summer tilt is ten degrees less than the latitude, while winter tilt should be ten degrees more than the latitude.

Central Arizona is at 35º latitude, so there the summer tilt should be 25º from horizontal. The winter tilt should be 45º.

In Vermont, at 44º latitude, the summer tilt should be 34º and the winter tilt 54º.

If snow or ice falls on the panels, it will need to be brushed off for the panels to work well. In some cases, it may melt off soon after sunrise.

It is usually not necessary to wash dust off the solar panels. If the panels are mounted close to the ground, mud may splatter on the panels which will need to be washed off. A partially covered solar panel will generate very little electricity, even if only 10% of the panel is covered.

Make sure the solar panels receive direct sun from at least 9 a.m. to 3 p.m. There should be no shade on the panels during this time. If just one single cell in a panel is shaded, the entire panel will not produce much electricity. Partial shading, by trees, bushes and obstacles, can rob the system of a lot of power.

Interpreting the volt meter

The volt meter can give a good idea how full the batteries are. This is very important, so the people in an off-grid home know how much electricity they can use. If too much is used, the batteries will be stressed. Over time, the users of the system will know how much can safely be used, simply by keeping an eye on the weather outside. People living with solar power tend to be well in tune with the climate for that reason.

There are various types of volt meters available. They either give the specific voltage on a display or show a bar of small lights to indicate how full the battery is.

The light-bar types are standard on most RVs and can also be purchased separately. They have the benefit that they are easy to understand. The downside is that they are less accurate than a real volt meter.

It is both an art and a science to correctly interpret what the volt meter says. It is not as simple as just reading off the number; one must also consider the circumstances, i.e. what is going on right now and a few minutes ago.

It is the easiest and most reliable time to read the voltage when the battery is at rest. The battery is at rest when no electricity is withdrawn from it and no electricity is added to it. Ideally, the battery should have been at rest for an hour before reading off the voltage.

The only time of day this may occur is in the morning, before sunrise and before any lights are turned on in the house. It may only be realistic to make such a reading during the dark winter months.

The second-best time of the day may be after sunset, before turning on the lights.

The table below shows how full a 12-volt lead-acid battery is, when at rest:

100%	12.75 v
95%	12.70 v
85%	12.60 v
75%	12.50 v
55%	12.30 v

45%	12.20 v
0%	12.00 v

Other times of the day, it is more an art to interpret the voltmeter. This is because when the battery is being charged, there is a higher voltage over the terminals. When the battery is being discharged, the voltage is lower.

How much the voltage will be off depends on many factors:

- how much charging (is it sunny/cloudy/dark, mid-day or early/late? How big is the solar panel)

- how much is being used (how many lights and other things are on)

- how big is the battery bank

- the temperature of the batteries

- the specific design of the system wiring

To get a feel for how your system handles, try to turn everything off. Watch the volt meter settle. Then turn on a lot of things. Watch the volt meter drop. Turn it all off, and watch the volt meter go back up again, perhaps slowly so.

Watch also how the batteries slowly fill once the sun is up. How the voltage slowly rises up to over 14 volts. If you use a simple on/off charge controller, you'll then see how the voltage goes back and forth between about 13 volts and 14 volts over some hours, until the charge controller is satisfied that the battery is full.

If you use a pulsing charge controller, the voltage will go above 14 volts and stay there for a long time, then go down to around 13 volts, as long as the sun is out.

If you consume some electricity, the charging cycle may start over again.

In the winter, the batteries may be cold. If your charger compensates for cold batteries, you may see the voltage climb above 15 volts.

By watching the volt meter over time, enough experience will be gained to know how the batteries really are doing. Some people have a volt meter mounted on the wall so they can easily glance at it throughout the day.

Temperature compensation

Batteries use a chemical process to store and release electricity. This process works best at room temperature. At lower temperatures the batteries get more sluggish. To ensure a cold battery gets filled, the charge controller will need to take it to a higher voltage. A battery that does not get fully filled at least every few days will eventually fail prematurely.

Fancy charge controllers have automatic temperature compensation. Simpler ones allow the user to manually change the set points (which is typically done four times a year). The cheapest charge controllers have fixed set points only.

If the batteries are stored where the temperature goes below about 60ºF (15ºC) in the daytime, temperature compensation should be considered.

The specific voltage set point varies with the battery. Check the manufacturer's web site for the correct numbers.

A general list is below:

Temperature	Set Point
0ºC 32ºF	15.3 volt
10ºC 50ºF	14.9 volt
20ºC 68ºF	14.6 volt
30ºC 86ºF	14.2 volt

When the battery is being charged at more than about 14.2 volts, there will be more generation of hydrogen gas. You may hear that as a bubbling sound. This is normal.

If your system does not have temperature compensation, you can instead do more frequent equalizations.

Equalization

The equalization process is when the batteries are intentionally over-charged. This is done by allowing the voltage to rise higher than is otherwise accepted, usually by an extra volt or so. This results in a vigorous bubbling of the batteries, while they off-gas hydrogen gas. This process makes sure the batteries are fully charged and stirs up the battery acid. Both are helpful for a long battery life.

Equalization is typically done after a period of deep cycling or where the batteries have not been fully charged for some days. It may simply be done routinely once every month or two.

This process is destructive to sealed batteries (gel-cel, sealed lead-acid, AGM, etc.). These types of batteries must be charged much more accurately, so equalization is never needed.

Some charge controllers automatically equalize the batteries. Others have a button for doing it. The simpler charge controllers will have to be bypassed by connecting the solar panels directly to the batteries. This can be done by a patch cord. However, the electronics in some charge controllers may be damaged by the higher voltage (this author did fry a SCI MARK 22 controller that way), so it is best to switch them off meanwhile.

The batteries will generate a lot of hydrogen gas during an equalization process. The batteries should be bubbling hydrogen for about an hour before the equalization is completed. If they do not, then the solar panels may not be large enough and a generator may be needed with a battery charger.

Adding distilled water

Lead-acid batteries contain strong sulfuric acid. Over time, some of the water in the acid is lost to evaporation and hydrolysis, where hydrogen and oxygen are released. If too much is lost, the lead plates will be exposed to air, which will damage them.

Every couple of months, you will need to check the water level by removing the battery caps. Distilled water must be added when needed. Regular distilled water from the grocery store is good. Water from a reverse-osmosis system is usually not as pure, but can be used in a pinch.

Make sure to wear protective eyewear and plastic gloves. Keep baking soda handy to neutralize any spills. Battery acid is very strong.

Deep cycle batteries have larger reservoirs than automotive batteries. The water level is fine as long as it is well above the lead plates.

Sealed batteries, such as AGM and gel-cell, do not have any liquid in them.

Cleaning the battery tops

The batteries should be kept clean for best performance and life. Dirt on the tops can create a conductive film that slowly drains power from the batteries. Corroded connectors should be cleaned, as they make for poor connections. Poor connections can result in uneven charging of the different batteries, with some never being fully charged and thus aging faster.

The tops can be wiped clean with wet paper towels. An old toothbrush or a wirebrush can be helpful to remove corrosion.

Special conductive grease can be used to coat the connections, to limit corrosion.

Troubleshooting

The sun shone all day, the batteries should be full, but the voltage after sunset is below 12.6 volt.

There can be many reasons why this is. Check the following:

- are the solar panels receiving direct sunlight the entire time between 9 a.m. and 3 p.m.?
- are there any obstacles which shade just a part of the solar panel(s)?
- the voltage across each and every battery. One or two batteries may be failing or not charging well.
- the set point on the charge controller is incorrect. If the batteries are cool (below 60ºF/15ºC), it needs to be higher than 14.5 volt to fully charge.
- clean the battery tops and any corroded terminals
- is there enough water in all the cells? (unless sealed)
- try to do an equalization (unless sealed)
- perhaps something is turned on?

I notice that the volt meter goes up and down pretty fast.

If the voltage flutters rapidly, like every second or so, then there is a loose connection from the charge controller to the batteries.

If the voltage stays above 13 volt and rises and falls once a minute or so, there are several possibilities:

- the battery is too small for the solar panel
- the battery is worn out, and does not accept the charge
- there is a loose connection between some of the batteries in the battery bank
- the set points on the charge controller are too close together

Suggested reading

Battery Book for Your PV Home, New England Solar Electric, 1991-2001, 22 pgs.

Off-grid Batteries – 30 Years of Lessons Learned, Allan Sindelar, Home Power magazine 140, Dec/Jan 2011.

Flooded Lead-acid Battery Maintenance, Richard Perez, Home Power magazine 98.

Living on 12-volt solar power for zero EMF, 2011. www.eiwellspring.org.