AJ's Technical Tips: Designing a Small Solar PV System Part III
Choosing a Battery for the System

Different types of batteries, including: automotive battery, solar battery, true deep cycle battery and a seal battery

Asante Sana for all of your letters! I want especially to congratulate Lloyd M. Muchiri of Chogoria for his excel lent design calculations for solar panel sizing. Lloyd answered my challenge to select a solar panel to provide the total daily energy for the system we have been designing over the last two articles based on the solar energy available during a cloudy month (see Solarnet vol. 4 no. 1 – in that article I made calculations to select a solar panel for the system based on the solar energy available in an average month, and then I asked readers to make their own calculations to select a solar panel if the design were based on the solar energy in a very cloudy month instead of in an average month). His correct calculations are as follows (in his own words):

> *In the last issue of Solarnet (vol. 4, no. 1) I was enlightened about designing a small PV system. And now I would determine the panel size for a cloudy month as follows:*
>
> *Energy requirement per day is 57 watt–hours. Therefore the current requirement will be 57 watt-hours ÷ 12 volts = 4.75 amps-hours per day. Now with the battery efficiency of 0.8 and the bright sun hours of 3.6 for Nairobi during the cloudiest month I get 4.75 amp-hours ÷ 0.8 ÷ 3.6 sun hours = 1.65 amps. Since I have known the current that we need from the panel is 1.65 amps, I now want to select the PV panel to give this power.*
>
> *According to the table on performance and price information on solar panels, I would choose two 15-watt Helios panels to give a total of 1.8 amps at a cost of 16,000 shillings.*
>
> *I will not just settle at this because of the price involved. Again I would throw my eyes on three 12-watt Free Energy Europe amorphous panels, which would give a current of 2.25 amps at a cost of 12,600 shillings. The Free Energy Europe solar panels will produce more current than the Helios and have a difference of 3,400 shillings lower cost. This will drive my conclusion to three Free Energy Europe panels as the best option for a 57 watt-hour per day requirement in a cloudy weather month.*
>
> *With the calculations above and the information given by the AJ's technical corner, I would be anxious to know why many people consider the crystalline panels as dominating compared to the amorphous types.*

I give Lloyd a perfect score for his correct calculations! With regard to the comparison between amorphous and crystalline panels, Lloyd is quite correct that high quality amorphous panels are less expensive per watt than crystalline types. This often makes the amorphous panels an excellent choice. Nonetheless, there are situations where crystalline panels are preferable. First, crystalline panels are more efficient than amorphous solar panels. This means that the amorphous panel has to be bigger in size (area) to produce the same amount of electric power. This does not matter very much for small systems, but for larger systems (for example, bigger than 50 watts) it can matter because amorphous panels may be heavy to carry to the installation site and they will also take up more space and require bigger mounting frames.

A second reason why crystalline panels are sometimes preferred is that they are harder to break than most amorphous solar panels. Amorphous panels that are made of a framed glass plate (for example Free Energy Europe, Phoenix Gold, Millennium, Kenital amorphous, etc.) are easier to break if they are dropped than crystalline panels, which are usually framed with stronger 'tempered' glass. Thus, crystalline panels are sometimes preferred even though they are more expensive because they are tougher when it comes to breakage. I should mention, though, that one type of amorphous solar panel is even tougher than the crystalline panels. Unisolar offers an excellent quality and highly durable amorphous panel. However, it is not cheap like the other types of amorphous panels so you have to decide if its extra toughness is worth the extra cost.

Now I want to proceed to discuss the main topic for this article, which is selecting a battery for the solar PV system that we have been designing over the last two articles. You will remember that in the first article (Solarnet volume 3, number 3) we calculated that the total daily energy use for this system was 57 watt-hours. This was for a system that had one 7-watt fluorescent lamp that was used for 3 hours per day, a black and white television (13 watts) that was used for two hours per day, and a 2-watt radio that was used for five hours per day. Then in the second article we selected solar panels to provide this energy. We decided that two 12-watt Free Energy Europe panels were the best choice for the solar panels based on their current output and their low price.

Now our task is to select a battery for the system. The first step is deciding which type of battery you want to use. In Kenya the four main types of batteries are (1) automotive starter batteries, (2) "solar" batteries, (3) "true deep cycle" batteries, and (4) sealed lead acid batteries. The first three types are all "wet cell" batteries, which means that their acid electrolyte is a liquid. The fourth type, the sealed batteries, have a gel type acid electrolyte that will not spill if the battery is tipped over. These are sometimes called "gel-cell" batteries. See Table 1 for a brief summary of these four types of lead acid batteries.

For solar applications you generally should <u>never</u> use the automotive starter type batteries because their design is not good for use with solar and they will not last very long. This is because their lead plates are very thin in order to deliver lots of quick power (amps) when starting an engine, but this makes them weak for use with solar where slow charging and slow,

Table 1: Common Lead Acid Battery Types

Battery Type	Typical Lifetime for Solar Use	Recommended Maximum Depth of Discharge	Notes
Automotive starter	Short (about 1 year)	20%	NOT for solar uses
Solar battery	Medium (2 to 3 years)	50%	Best for small solar PV systems
True deep cycle	Long (4 to 6 years)	80%	Best for larger solar PV systems
Sealed	Medium (2 to 3 years)	40%	Best for lanterns and other movable PV systems

deep discharging are normal.

"Solar" batteries are better than automotive starter batteries for solar uses because the solar batteries have thicker lead plates. This helps them last longer.

Even better than the solar batteries are the "true deep cycle" batteries. These include both the tubular plate type batteries and flat plate batteries that have very thick plates. These are the type of battery that lasts the longest in solar uses, but they are also expensive and they are often not available in small sizes (they generally are 100 amp-hours or larger) so they usually cannot be used with small solar PV systems. However, they are usually the best choice for larger solar PV systems.

Finally, a fourth type of battery that is available is the "sealed" lead acid battery. These batteries are not true deep cycle batteries, and they seem to last about as long as the "solar" batteries for solar uses. However, they are more expensive than "solar" batteries so they are not the best unless there is a special reason to use them. The main advantage of the sealed batteries is that the acid inside them will not spill out, so they are good for use in solar lanterns or other uses where the battery is moved around a lot.

For most small solar PV systems like the one we are designing "solar" type lead acid batteries are usually the best choice and that is the type that I will recommend for this system.

Once we have decided that we are to use a "solar" type battery, the next step in our process of selecting a battery for the system is calculating the best amp-hour size for the battery. This calculation has four parts.

1) Daily energy use for the load (watt-hours per day) ÷ system voltage (volts) = daily load amp-hour requirement for the system (amp-hours per day).

   - For our system this is 57 watt-hours per day ÷ 12 volts = 4.75 amp-hours per day.

2) Daily load amp-hours per day X number of days of storage in the battery required = total battery storage required (amp-hours)

   The number of days of storage is the number of days in a row that the system could operate without getting any energy from the sun if you start out with a fully charged battery. I will use five days of battery storage for this system (as explained below).

   - For our system this is 4.75 amp-hours per day X 5 days = 23.75 amp-hours of storage required.

3) Amp-hours of storage required (amp-hours) ÷ maximum depth of discharge for the battery = approximate battery size (amp-hours).

   My recommendations for the maximum depth of discharge for different battery types is given in table 1. For our system we are using a "solar" battery so the number is 50%, or 0.50.

Wrapping of wire around the terminal, and not connected properly is a poor connection

   - For our system this is 23.75 amp-hours ÷ 0.50 = 47.5 amp-hours battery size.

4) Finally, round up to the next nearest battery size that is available in the shops. In our case this is a 50 amp-hour solar type battery.

Before picking the lowest cost battery that will meet the customer's needs, I want to briefly discuss two issues.

The first is the issue of deciding how many days of battery storage are required for the battery. This number is an estimate based partly on the weather for the area during cloudy periods, partly on practical considerations of how easy or difficult it is for the end-user of the system to charge the battery if there is no sun (for example, by taking it into town for a charge or by using a generator), and partly on the preferences of the customer.

In areas, which have many days without sun in a row during the cloudiest period of the year, it is good to have more days of energy storage. I usually use five days of storage for towns around Mount Kenya or other areas with many cloudy days, and I use four days of storage in areas with a bit more sun (for example, Nakuru or Kisumu).

However, for solar PV systems that are far from any battery charging shop and where there is no other way to charge the battery (for example with a generator) when there is no sun then I give the system a few extra days (about 7 or 8 days total) of battery storage so that the customer will have enough energy during the cloudy periods. In general, if you are not sure how many days to put then five days of storage is often a good number.

The second issue that I want to discuss briefly is the maximum depth of discharge for the battery. This number depends on the battery type, and I have given values for this number in Table 1. This number is the maximum percentage of the battery storage capacity that the customer should use if he or she wants the battery to last a long time. If more energy is taken from the battery than this amount and the battery is taken to a very low voltage then the battery is being damaged and it

Table 2: Information About Some 50 Amp-Hour Batteries Sold in Kenya

Battery Brand	Battery Size (amp-hours)	Battery Type	Battery Retail Price (KShs.)	Price per amp-hour (KShs./Ahr)
Chloride Exide	50	Solar	5,100	102
Voltmaster	50	Solar	4,400??	88??
AP	50	Solar	4,200??	84??
Chloride Kenital	50	Solar	4,500	90
NS50	50	auto-motive / starter	3600	72

A solar battery with a proper wire connection for a battery terminal

will not last nearly as long as it should! It is very important to explain this to your customers so that they can conserve energy or take the battery for a charge as soon as they think it may be getting low. Of course, this can be difficult because without a volt meter or some other way of knowing the charge of the battery it can be hard for users to know when the battery is getting low. I will discuss this topic of helping customers know when the battery is getting too low as well as the role of charge controllers and low voltage disconnects for protecting the battery in my next article.

Now that I have discussed these issues I would like to proceed to the next step in the process of selecting a battery – this is looking at the prices of batteries that are available in Kenya and picking a high quality battery that does not cost too much. See Table 2 for some information about some 50 amp-hour batteries that are available in Kenya. I thank Maina Mumbi for his assistance in collecting this price information about batteries sold in Kenya.

So far we have decided that we want to use a good quality "solar" battery that is 50 amp-hours in size. There are several different brands of 50 amp-hour solar batteries that are available in Kenya. These include Chloride Exide, Voltmaster, AP, Chloride Kenital, and others. When buying a battery it is important to consider the price, but it is not always best to just buy the cheapest battery since some batteries are better than others.

I have not done complete testing of all the different battery brands in Kenya, but from my experience I would recommend either a **Voltmaster** or a **Chloride Exide** battery for the 50 amp-hour size that we want for the system. These are good quality batteries that come with a one-year guarantee. Both of them sell for about the same price, so I would recommend either one for the system. However, you might find prices that are different from the ones I report here, since different shops offer batteries at different prices. Note also that some of the other battery brands are less expensive - including the automotive starter battery - but this does not necessarily make them a good deal since they may wear out much sooner.

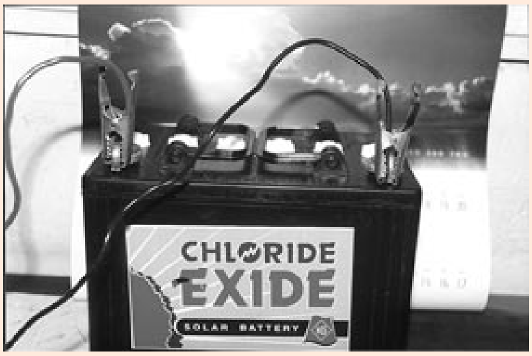
When you buy a battery make sure that you get a written guarantee of at least one year, and be sure also to keep the receipt for the sale so that if there is any problem you can return the battery. You should also advise your customers to be careful about keeping the written guarantee and the receipt. I have seen many batteries and solar panels that have failed during the guarantee period, but they cannot be returned because the customer has lost the receipt. Do not let this happen to you.

Also, when you buy the battery be sure to get good battery terminals for connecting the wires to the battery. See Figure 1. It is not good to use clips or to just wrap the wires around the battery posts because these do not give a good connection. Battery terminals with screw connectors give a good connection and this is important for making sure that the system is safe and efficient. Once you have made the battery connection you can put petroleum jelly (e.g. vaseline) on the wire connections at the battery terminals to protect them from corrosion from the battery acid.

Finally, I recommend that you always buy batteries that have been stored at the shop "dry" - that is, the acid has not yet been put into the battery. The acid should be added when you buy the battery and are ready to install it in a system. This is because it is bad for a battery to sit for a long time without being used with the acid in it. If this happens the battery gets damaged and it will not last very long. Most battery manufacturers and vendors are good about selling their batteries "dry", but I have heard some stories recently about some imported batteries that have been sold "wet" in Kenyan shops. These batteries did not last long and the customers were very unhappy with their performance.

To conclude, in this article we have used information about the daily energy used by the loads to select a battery for the small solar PV system that we are designing. The first step is deciding which type of battery to buy. We chose to use a "solar" battery because this is the best choice that is available for small solar PV installations. Next we made calculations to determine the size of the battery, and for this system we chose a 50 amp-hour size. Given our daily energy usage estimates, this will give up to 5 days of energy storage without any input from the sun during cloudy periods. Next, we looked at the different brands of batteries that are available in Kenya in the 50 amp-hour size to decide on a good quality 50 amp-hour battery with a reasonable price. Based on my experience with the batteries and current retail prices I recommend either a Voltmaster or a Chloride Exide 50 amp-hour solar battery. Finally, I gave some general advice about buying batteries. It is always important to get a written guarantee of at least one year and to keep the receipt in case you need to return the battery later. It is also good to spend a little extra money to get good battery terminal connectors. Last but not least, it is important to buy batteries that are stored "dry" - the acid should only be added to the battery after it has been bought and you are ready to install it.

I will finish this article with another challenge to you the readers. In the last three articles (including this one) we have made a design for a small PV system. The process started with calculating the size of the electrical loads for a system, then we selected a solar panel for the system based on the sun available at the installation site, and finally we have selected a battery for the system. To practice your skills in making all of these calculations, I would ask you to make them for a solar PV system that you have installed recently (or for a new system that you are about to install). That is, for an installation that you did recently (or are about to do) calculate the daily energy for the loads based on the electrical uses and the estimated time that they are to be used. Then using this number select a solar panel and a battery to meet those loads for the location of the installation. Note that the solar panel and battery size that you calculate this way may be different from the ones that you actually installed at the system. If you write me with your calculations I will be sure to check them and write you back with any suggestions I might have.



Use of clips to connect wire to the battery terminal is one of the wrong ways of making the connections

In my next article I will write about wiring the solar PV system - including wire sizing and selecting wires to connect the different parts of the system. I will also talk about charge controllers and their use in small solar PV systems. Until then, kwaherini and salaam to you all!

Arne Jacobson
arne@socrates.berkeley.edu