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**AJ's Technical Tips:** Charge Controllers and Small Solar PV Systems

Steven Ojiambo wrote me a letter recently with a question about wiring. He asked, *"Is it possible to use the same wires for a residential house for DC loads (solar) and AC loads (mains)?"* I talked about this issue a little bit in the last issue of Solarnet (volume 5, number 1), but I did not explain it in detail.

The answer is "yes", it is possible to design the wiring for a house so that it can be used either for DC or AC loads. You might want to do this if you are installing a solar system now, but you (or your customer) want to be able to connect to the AC mains later without re-wiring the house. To do this you need to remember two things. First, the wire sizes for 12 volt DC loads are almost always larger than the wires sizes for AC loads. This means that you should design the system so that the wires are big enough for the DC loads. I explained how to pick the right wires for a DC system in the last issue of Solarnet. Second, although small DC systems often do not require earthing, AC mains systems always require earthing. This means that you should wire the home using cables that include an earthing conductor wire. The "twin with earth" (T/E) cables are the right choice in this case. To summarize, you can wire a house so that it can be used with a DC solar system or AC mains by making sure that the wires are big enough for the DC loads and by using T/E cables (that is, cables with an earthing wire).

In this article I will discuss charge controllers and their use in small solar PV systems (charge controllers are sometimes also called charge regulators). Most small solar PV systems in Kenya do not include a charge controller. In many cases this is because the system owner (the customer) has decided not to use a charge controller because they do not believe that it will help make their system work better and because it is too expensive. Many solar experts from around the world say that this is a big problem, that batteries last longer when they are used with a charge controller, and that more people should use controllers. Who is right in this case, the rural Kenyan solar users or the solar experts?

I have two answers to this question. First, for very small systems (less than 20 watts) it is ***sometimes*** OK not to use a charge controller, but for larger systems (more than 20 watts) it is almost always best to use a controller.

Second, a few of the charge controllers sold in Kenya are a bad investment as they do not do a good job at protecting the battery, while other charge controllers are a good investment. I will spend some time in this article talking about how to select a good charge controller for the system you are installing.

The first step in talking about charge controllers is explaining what they do. There are five main things that a charge controller can do to help a system operate better. Some controllers are better than others at doing these five things, and you should consider all of them when you are selecting a charge controller for a system. These are (1) protect the battery from being overcharged, (2) protect the battery from deep discharge, (3) prevent energy loss from the battery at night, (4) protect the system from high currents with a fuse, and (5) give information about the condition of the battery through a display or indicator lights. Some charge controllers do all of these things, while others only do some of them.

1) **Protect the battery from being over-charged**. Frequent over-charging can damage a battery quickly, and charge controllers help protect against this problem. Different types of controllers do this in different ways. Some controllers simply disconnect the battery from the solar panel using a relay switch when the battery reaches a certain high voltage (for example, 14.4 volts). This "relay" type of controller is OK, but it is not the best. Other controllers have more complicated (and better) ways of controlling the voltage so that the battery gets a good charge without being damaged by over-charging. Controllers that trickle charge the battery (that is, charge the battery with a very small current) when it is almost full are better than controllers that simply disconnect the battery when it reaches a high voltage. Some controllers have a special way of charging the battery when it is almost full called "pulse width modulation" (PWM) - this type of controller gives the battery an even better charge than trickle charging and can lead to longer battery life. The PWM charge controllers can be a bit more expensive, but often they are worth it due to their higher performance. One final issue that is important to know is that some types of batteries are more sensitive than others to over-charging. *Sealed lead acid batteries (including "gel cells") are especially sensitive to over-charging*. You should *never* use a sealed battery without a charge regulator, and with these batteries it is *very important* to use a charge controller that is especially designed for use with sealed batteries. If you do not do this, the sealed battery will get damaged very quickly. Some charge controllers have settings that you can change depending on if you are using a regular lead acid battery or a sealed battery. See Table 1 for a list of charge controllers that have this feature.

2) **Protect the battery from deep discharge with a Low Voltage Disconnect (LVD)**: Discharging a battery deeply also damages the battery. In general, if the voltage of a battery goes below 11.8 volts it has been discharged deeply, and the lower it goes beyond this the worse it is for the battery. It is bad for the battery to be discharged deeply, and it is even worse for a battery to stay at a low voltage for a long time. The best thing to do if a battery is discharged deeply is to *recharge it fully* as quickly as possible. Deep discharge is the *main* reason that batteries wear out quickly in solar systems. A low voltage disconnect (LVD) can help protect a battery from damage from deep discharge, although it is still important to recharge the battery fully even if a LVD is used. Some charge controllers include a low voltage disconnect (LVD), and some do not. Controllers that do have an LVD make the disconnection at a number of different voltages depending on their settings. From my experience and knowledge about batteries, the LVD should not be set lower than 11.5 volts, and my preferences is for an LVD of 11.7 or 11.8 volts. When it is set lower than 11.5 volts the LVD does not give the battery very much protection because the battery is being damaged when it goes below this voltage. Some controllers even have the LVD set as low as 10.5 volts - this is much too low to give good protection to the battery! I know that some people do not like LVD's that are set at 11.5 volts or higher because they say that this does not let them use all the energy in the battery. Some system users will even bypass

the LVD because they do not like to have the battery cut out while they are watching TV or using a light.  I understand this problem, but I also know that the battery is being damaged when it is used at voltages below 11.5 volts.  For this reason I recommend the higher LVD settings and I work hard to explain to people that this higher setting helps protect the battery so that it can last longer.

3) **Prevent energy loss from the battery at night:** At night a small amount of current can flow out from the battery and up through the solar panel.  This is a loss of energy, and it reduces the amount of energy that is available to power lights, TVs, radios, etc.  A diode can be installed in the wire between the battery and the solar panel to prevent this problem, and many solar systems include a diode for this reason.  Most charge controllers include a diode or another way of preventing this problem.  If you use a charge controller that does give this protection is, then it is not necessary to install a diode in the system.

4) **Protect the system from high currents with a fuse**: Most charge controllers include a fuse in the circuit.  This fuse usually protects the circuit from the solar panel to the battery and also the circuit from the battery to the loads.  A few charge controllers include an automatic electronic circuit breaker switch instead of a fuse.  The circuit breaker is nice because it is not necessary to replace it if the current goes to high – instead the circuit breaker resets itself automatically after the short circuit or high current problem is fixed.  In either case (a fuse or a circuit breaker) this is a good thing to have!

5) **Give information about the condition of the battery through a display or indicator lights**: One of the important things that a controller can do is provide the user with valuable information about operation of the system, including the condition of the battery.  For example, many controllers have small indicator lights that show if the battery is full, empty, or somewhere in the middle.  It is also common for a controller to show if the solar panel is charging the battery or if the battery voltage has reached the low voltage disconnect (LVD) voltage. Some controllers – often the more expensive ones - also use a display screen that provides additional information about the system.  When I am choosing a charge controller I always make sure that it includes information about the condition of the battery.  It is important for the users to know if the battery is full or if it is low so that they can cut down on their use if the battery is going low.  I also check to make sure that the information given by the controller will be easy for the people who are going to use the system to understand.  Then when I install the system I take time to carefully explain the indicator lights or the display to the system users.  This is very important, because people cannot make good use of the information if they do not understand how to read it!

These are the five main things that charge controllers do in a system.  There are a few fancy controllers that do a few additional things, but these are the main things that a controller can do.  Of course, doing these things takes some energy, and some controllers use more than others.  That is, the controller uses a little bit of current from the solar system to do its work, and this means that a little bit less energy is available to charge the battery. The amount of energy used by the controller can be especially important in small systems. If the controller uses a lot of energy, then there might not be very much left for charging the battery! This means that you should look for a controller that does not use very much current to do its work. This is one more thing that you should look at when choosing a controller.

I will now spend some time talking about how to select a charge controller for a solar system. I will do this by using an example from a solar PV system that I designed for a house near Nyeri a few months back. The solar system had a 30 Watt solar module (Astropower) and a 50 amp-hour battery (Voltmaster). It was designed to power five lights and a mobile phone. Four of the lights were 6 watt fluorescent tube lights by Sundaya (in the kitchen, sitting room, and two bedrooms), and the other light was a 15 watt incandescent bulb (in the corridor). I decided to use an incandescent bulb in the corridor because this light was not going to be used very often.

I chose to use a "Sollatek SPCC 6" charge controller with this system. See Table 1 for more information about this controller and some of the others that I considered using with the system. Note that Table 1 is only a short list of some of the controllers that are available in Kenya. There are other types and sizes, including a number of charge controllers that have current ratings that are bigger than 10 amps. You can get information about some of the other charge controllers that are available by asking for specifications from solar vendors. I recommend that you never buy a charge controller without a proper specification sheet that has good information about the performance of the charge controller.

My decision to choose the "Sollatek SPCC 6" charge controller was based on several factors, including price, its current rating, its method for protecting the battery from overcharging, its LVD setting, the display that it used to give information to the system end user, and other factors. I will now take some time to explain why I chose the "Sollatek SPCC 6" controller instead of the others. I should also note that while I picked the Sollatek controller, some of the other controllers – including the "Morningstar Sunsaver 6" and the "Stecca Solarix 8.8" – could also have been good choices.

The first step in choosing a charge controller for this system was sizing the current rating for the charge controller. Charge controllers actually have two current ratings. See Table 1. One rating is for the current from the solar panel to the battery, and the other rating is for the current from the battery to the loads. Often these two ratings are the same and they are given as a single number. For example, the "Sollatek SPCC 6" charge controller in Table 1 has a rating of 6 amps. In this case this means that the maximum current from the solar panel to the battery is 6 amps and the maximum current from the battery to the loads is also 6 amps. For some charge controllers these two numbers are different. For example, the "Morningstar Sunsaver 6" is rated for 6.5 amps from the solar panel to the battery and 10 amps from the battery to the loads. When you are choosing a charge controller you will need to know both of the current ratings – that is, the rating from the solar panel to the battery and from the battery to the loads.

In the 30 watt solar system for the home near Nyeri the maximum current from the solar panel to the battery was 2 amps, and the maximum load when all of the lights were on and the mobile phone was charging was about 3.5 amps. This meant that I needed a charge controller that was rated at 3 amps or more from the solar panel to the battery and

4 amps or more from the battery to the loads. It is often a good idea to choose a charge controller with somewhat higher current ratings than the maximum at the time of the installation in case the system owner wants to add a solar panel or more loads later. For this system I decided that the controller should have a rating of at least 5 amps from the solar panel to the battery and at least 6 amps from the battery to the loads. This sizing allowed for the possibility of future additions to the system without changing the charge controller.

**Table 1: Specifications for Selected Charge Controllers for Small Solar PV Systems**

| **Brand / Type** | **Rating** **(solar to battery)** (amps) | **Rating** **(battery to load)** (amps) | **LVD setting** (volts) | **Charge Reg. Type [1]** | **Fuse Type [2]** | **Price** (KSh) | **Current Use** (mA) |
|---|---|---|---|---|---|---|---|
| Sollatek – SPCC6 | 6 A | 6 A | 11.5 V | PWM | Auto | 3,450 | 8.5 mA |
| Morningstar SunGuard | 4.5 A | Any | None | PWM | None | 3,280 | 6 mA |
| Morningstar Sunsaver-6 | 6.5 A | 10 A | 11.7 V | PWM* | Auto | 4,890 | 8 mA |
| Kenital K5 | 4 A | 4 A | 10.5 V | Trickle | None | 2,200 | 1.5 mA |
| Helios HT5 (Kenital) | 5 A | 8 A | 10.8 V | Trickle | Auto | 2,800 | 6 mA |
| Sanyug 04.04 | 6 A | 6 A | 10.8 | Relay | 8 A | 2,700 | 8 mA |
| Stecca Solarix 8.8 | 8 A | 8 A | 30% SOC | PWM* | 10 A | 5,500 | 7 mA |
| Stecca Solsum 6.6 | 6 A | 6 A | 11.1 V | PWM | 6.3 A | 2,900 | 7 mA |

**Table 1 Notes:**

**[1] Charge regulation type**:

(see the section called "**Protect the battery from being over-charged**" for more information)

"PWM" = "pulse width modulation" charge regulation

"Trickle" = trickle charge regulation charge regulation

"Relay" = simple relay disconnect switch charge regulation

* = this type of controller is OK for use with sealed batteries (the others are NOT)

**[2] Fuse Type:**

(see the section called " **Protect the system from high currents with a fuse** " for more information)

"Auto" = automatic electronic circuit breaker

"8 A" = this indicates a standard fuse (in this case 8 amps)

"None" = no fuse included

From Table 1 you can see that most of the controllers have current ratings that were OK for the system that I was designing, while one did not. The one that is too small is the Kenital K5 controller. This one would not work for the system near Nyeri because its current rating is 4 amps, and this is too low for the system since I wanted a rating of at least 5 amps from the solar panel to the battery and 6 amps from the battery to the loads. All of the other charge controllers that I have listed have current ratings that are OK.

However, the current rating is only one thing that I considered when choosing a charge regulator. I was also interested to get a regulator that protected the battery well from deep discharge. For this reason, I looked carefully at the "Low Voltage Disconnect" (LVD) features of each charge controller. As I discussed before, I wanted a LVD setting that was 11.5 volts or higher. Only two of the charge controllers in Table 1 have a LVD setting that meets this standard. These were the "Morningstar Sunsaver 6" (LVD at 11.8 volts) and the "Sollatek SPCC 6" (LVD at 11.5 volts) controllers. A third controller, the "Stecca Solarix 8.8" controller, uses a special system that take several factors – including voltage but also some other factors - to disconnect the battery when the state of charge is at 30%. A cut off at 30% state of charge is about the same as an LVD setting of 11.8 volts, and this system of using several factors to decide when to disconnect the battery is better than a cut off that only depends on voltage. Finally, as I mentioned before in this article, some of the charge controllers listed in Table 1 have a LVD setting that is as low as 11.1 or even 10.5 volts. These LVD settings do not protect the battery very much as damage has already been done to the battery by the time it has reached these low voltages.

Another factor that I considered was the method that is used to protect the battery from overcharging. I prefer the pulse width modulation (PWM) approach to charging the battery because it gives excellent protection against overcharging while also helping to ensure that as much of the sun's energy as possible is delivered to the battery. Many of the charge regulators listed in Table 1 use the PWM approach, including the Sollatek, Morningstar, and Stecca charge controllers.

After looking at the current ratings, the LVD settings, and the overcharging protection, I was interested to buy either the "Sollatek SPPC 6", the "Morningstar Sunsaver 6", or the "Stecca Solarix 8.8" charge controller. Of these three, I was most interested in the Sollatek controller because it had the lowest price (see Table 1). Of course, some of the controllers listed in Table 1 are even less expensive than the Sollatek controller, but I was not interested in these because they did not perform the way I wanted. In particular, the lower priced charge controllers had LVD settings that were too low.

However, before making a final decision to buy the Sollatek controller I considered a few additional factors. First, I wanted to get a charge controller that included a fuse or some other way of protecting the circuits against high currents. Most of the controllers have either a fuse or an automatic circuit breaker to protect the system from short circuits and other high currents. Table 1 shows that several of the controllers use an automatic circuit breaker, including the "Sollatek SPCC 6", the "Morningstar Sunsaver 6", and the "Helios HT5" controllers. Several others use a fuse, including the Sanyug and the Stecca controllers. Fuses and automatic circuit breakers are both OK, but I prefer the circuit breakers because they automatically reset themselves after the high current problem is fixed.

I also wanted to get a controller that provided good information to the end user about the operation of the controller and the condition of the battery through a display or indicator lights. From my experience it is very important to choose a charge controller where the information is given in a way that is easy for the system user to understand. Most of the controllers in Table 1 use indicator lights to give information about the system, and one of the controllers, the "Stecca Solarix 8.8", also has an optional display which is easy to understand and which gives useful information about the condition of the battery.

I like the system of indicator lights used by the “Sollatek SPCC 6” controller to present information to the end user. This controller uses five colored indicator lights (two of the lights are green, one is yellow, and two are red). Three of the lights are used to give information about the condition of the battery. A green light is lit when the battery is “full” (or almost full), a yellow light is lit when the battery has a “medium” charge, and red light is lit when the battery is “low”. Another light (green) shows if the solar panel is charging the battery, and the last light (red) indicates if the LVD has been used to disconnect the battery from the loads. Each indicator light has a small label next to it to explain the meaning of the light. This information can be very valuable to system users if they are able to understand it. For example, if the indicator light shows that the battery is getting low they can reduce their use of electric loads until the sun comes out to charge the battery again. If they do this instead of using the system until the LVD disconnects the battery then the battery can last longer.

I find that this system of indicator lights for the “Sollatek SPCC 6” is a bit easier to understand and to explain to system users than some of the other charge controllers listed in Table 1. For example, the “Morningstar Sunsaver 6” controller gives more or less the same information as the “Sollatek SPCC 6” controller, but it uses only three indicator lights to do this. This is done by having each of the lights give two kinds of information depending on whether they are “on” or if they are “flashing” on and off. That is, if the red light is “on”, then the battery is in a low state of charge. If the red light starts flashing on and off, then this means that the LVD has been used to disconnect the battery from the loads. This system of giving information is OK, but from my experience many system users have a harder time learning how to understand the information that is being given to them by controllers that use the same light to give more than one type of information. For me this is an important difference between these two charge controllers, as I always want to choose the controller that gives good information in a way that is easy to understand. I will not give a complete description of all the different systems that are used in the different charge controllers to give information to the users, but I do recommend that you always look carefully at the way that each controller displays information to the system users to make sure you think that the information will be easy to understand.

After considering all of these things, I still wanted to buy the “Sollatek SPCC 6” controller because it was the lowest priced controller among the ones that had the specifications that I wanted. There were a few final things that I checked before buying the Sollatek controller. I made sure that the wires that I wanted to use with the system (2.5 $mm^2$) would fit in the wire terminals for the controller. The “Sollatek SPCC 6” controller can be used with wires up to 6 $mm^2$ so that was OK. I also checked to see if the controller protected the battery from energy loss back through the solar panel at night. Like many charge controllers, the “Sollatek SPCC 6” does protect against this energy loss and because of this I did not have to install a diode in the system.

Finally, I checked to see how much current the charge controller uses in order to be sure that it is not too high. From the manufacturer’s specifications I found that it uses about 8.5 mA (milliamps). This is energy from the solar panel that cannot be used to charge the battery, so it is important to make sure that it is as small as possible. I estimate that the energy use by the charge controller in this case is about 2% of the total energy produced by the 30 Watts solar panel that I installed with the system. This is a small amount of energy, but some controllers use more energy and they can reduce the amount of energy available for charging the battery by a lot. In general for solar systems that have a solar array that is 40 watts or smaller I recommend that you use charge controllers that use 10 mA or less. Most of the charge controllers that are now sold in East Africa for small solar systems do not use more than 10 mA (so they are OK), but you should still check the official manufacturer's specifications to be sure. For larger solar systems it is OK to use a controller that uses a little bit more current than this, and some of the high quality controllers that have a display screen do use a bit more.

To summarize, I chose the "Sollatek SPCC 6" charge controller for the system that I was installing near Nyeri after considering its price, current rating, LVD setting, its method for protecting the battery from overcharging, the display that it uses to give information about the battery to the systems users, and a few other factors. The system has been working for over six months and so far the Sollatek controller has performed very well.

Based on my experience and their manufacturers' specifications some of the other controllers that I considered – including the "Morningstar Sunsaver 6" and "Stecca Solarix 8.8" controllers – would also have been good choices. And of course there are other charge controllers available in Kenya that you might want to use, including a number of controllers with higher current ratings. If you are looking to buy a charge controller I recommend that you ask for information about the controllers from the different solar vendors. Then you can decide which controller will be best for your system after considering all the different factors that I talk about here.

I want to finish this article by going back to the question of whether or not it is important to use a charge controller in solar systems. As I said before, if you buy a good quality charge controller it can be a wise investment for systems that are larger than 20 watts. This is mainly because a good quality charge controller can help the battery to last longer and this saves money! For smaller systems it is sometimes OK not to use a charge controller. The decision about whether to use a controller in a small system is really an economic choice about finding the best way to make the system work as well as possible. In my experience the biggest problem for small systems is that the battery gets damaged quickly because of deep discharge. A charge controller with an LVD set at 11.5 volts or higher can help protect against deep discharge, but adding a second small solar panel (e.g. 14 watts) might be even better for helping the battery to stay at a higher state of charge while also increasing the amount of energy that is available in the system. In my opinion, if the owner of a small solar system has 3,500 KSh to spend on a good quality charge controller, she or he might consider spending that money plus a little bit more to buy a second good quality solar panel for the system (at a cost of about 4,000 KSh) instead of buying a charge controller. Of course, if enough money is available to buy both then that is best, but often there is not enough money to do this. It is for this economic reason that it is sometimes OK not to use a charge controller for small systems, but for larger systems it is always best to use a good quality charge controller.

I am interested to hear your views on this issue, so please write me to tell me about your experiences or ideas about charge controllers or any other questions or comments you might have. I will discuss them in my next article. Until then, *kwaherini*!