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Solar Solution to meet the basic electrical needs (lighting and charging) of people in rural or disaster areas disconnected from grid utilities (link to original article)

Abstract:

This documents serves as an introduction to the potential of small solar systems to:

a) Provide basic lighting and mobile phone charging facilities for residents in rural areas with no access to grid electricity
b) Elaborate on the application of such systems in the provision of mobile phone charging facilities or convenience lighting in public spaces (which may align to a Corporate Social Responsibility initiative or Marketing opportunity)

Results:

Based on investment of R 645* [ZAR] / < 50$* [USD], I was able to generate power equivalent to accomplish one of the following:

a) Daily: 10 hours of light a night from a 3 watt DC light bulb, with the possibility of additionally providing a charge of a simple feature mobile phone (6 watt-hour consumption) – **Tested**
b) Daily: 4 charges for an average Smartphone at (10 watt-hour consumption)
c) Daily: 42 watt-hours of energy to power other small devices

*(consumer prices as of Nov 2015, note: manufacturing at scale will significantly reduce the cost)

Based on experience with similar electrical components this system with further testing and development could in theory withstand 5-7 years of continuous use.

Applications:

- *Rural area lighting and charging solution*
  - Initially developed and tested for this purpose. Provision of an inexpensive basic lighting and charging solution for rural settlements waiting for infrastructure. Solution could be delivered assembled or in components to reduce effort in trans.

- *Bus stop charging advertisement option*
  - System could be permanently installed at a bus stop and supply waiting commuters with a mobile phone charging service. Advertisement could be placed near or on the device.

- *Mounted pole grid system*
  - System could be assembled in the form of poles (similar to the image provided) which could be pushed into the ground in a grid format to cater for emergency lighting or provide a small grid solar solution quickly.

- *Power supply for a radio system/ Wi-Fi system to distribute news and updates in disaster areas*
  - System could be used to power radio's/ Wifi devices over a selected area to update people in a disaster area or form a mesh network

- *Extensions of use:*
  - Remote receiver could be added to put light on at the press of a button. Night or Timer switch could be added to automatically put light on and off when dark or during specific times.

Introduction:

About a year ago, I thought about working on a rural solar solution. The main philosophy behind this was my desire to understand how to extract maximum value out of minimum investment in the provision of basic services.

Investigations led me to engage people who inhabit or frequently visit rural areas of Africa. What I elicited from this was there are two very basic requirements:

1. Light
2. Mobile phone charging facilities

Taking the above into account, financial abilities of the average informal resident and the accessibility to goods and services, I added a few more requirements:

3. Inexpensive to build
4. Inexpensive to expand or maintain
5. Easy to operate, fix and maintain
6. Provide some level of upgradability to grow with the needs of the person or family

Components:

As a result of my requirements, I eventually decided on the following components:

1. 3w DC led light
2. 7 AH Alarm Battery
3. Cigarette Lighter socket fitting
4. 10A charge controller
5. 20W solar panel
6. Simple Box (Ice cream container is fine)
7. Wiring

3 Watt Led Light

Not taking into account inefficiencies a 3w Led light should consume 32/12v = 0.25A worth of battery power. With the 7 amp hour battery an estimated 14 hours of run time can be achieved on **half** the battery capacity under perfect conditions. In testing, 10-11 hours were achieved over a 3 month period without any obvious degradation of the battery.

7 AH Alarm Battery

This specific battery was chosen for four specific reasons:

1. It is easy to find and purchase, with most stores stocking the required size
2. It can withstand a daily discharge of 50% with an acceptable level of degradation considering its price.
3. Is 12V, as such compatible with a lot of other electrical components available
4. Can provide more than enough capacity to power the selected globe for 8 hours or more a night and charge an average feature phone

*Pure deep cycle batteries are relatively expensive and not easily available.

Based on the choice of battery, in theory 84 watt-hours of battery power can be stored if the entire capacity is used. To avoid accelerated degradation of the batteries ability to hold a charge however the system was designed around charging and utilizing only half this capacity, 42 watt-hours (3.5 aH).

20 Watt Solar Panel

The Solar Panel will convert light/Sunlight into Electricity. The chosen panel should produce 20w/12v = 1.6 Amps of current in perfect conditions. Using 80% efficiency as a baseline for losses, the ultimate current reaching the battery should be 1.6 x 0.8 = 1.3 amps.

This so happens to be the maximum current the chosen battery (7 AH) can absorb. The general rule of thumb is that a battery can be charged at a max of 20% its total capacity.

Taking into account that we do not plan on discharging the battery more than 50%, to limit battery strain and promote a longer battery life. The chosen panel in conjunction with the battery size should allow us to change the system back to capacity in less than 4 hours.

Other inefficiencies however do exist. Africa is indeed full of sunlight but we do get cloudy days and solar systems are not 100% efficient either. As such, a 20 watt panel was opted for which in testing charged the required capacity in the battery within 4-5 hours.

The size of the panel may seem unwarranted since Johannesburg (where the unit was tested) receives 8:42 hours of sunlight on average. Bearing in mind though that the system was designed to be used in a range of rural areas, it was believed that the choice would be fine for most climates.

10A Charge Controller

A 10A charge controller in terms of capacity may seem a lot for this size of system. Considering the requirements for accessibility and upgradability it was found that this particular size was easier to source. Smaller sizes where sold in specialty stores and was deemed too restrictive for meeting the purposes of the system produced.

A charge controller regulates the manner in which the battery is charged from the solar panel, and how that charge is transferred to a device for consumption. A solar panel generally creates an output between 16-18 volts of electricity whilst a battery needs to be charged between 11-13 volts depending on where it is in its charge cycle.

Due to the above, a charge controller is required to:

1) Adjust the voltage down to something that will not damage the battery
2) Change the rate of charge to what the battery requires at different charge cycles

In summary, a charge controller is required to protect the battery while charging it.

Cigarette Lighter socket fitting

The component was included to allow a person to use standard car charging devices to charge their mobile phone. The socket also serves to increase the potential of the device as it provides current similar to what a vehicle socket would be able to produce, potentially allowing it to be used with other 12V car accessories.

The Box

A standard plastic box and later a 2L ice cream container was tested for suitability. No specific box is needed however any box chosen needs to meet three requirements:

1. Shelter the battery, charge controller and connections from direct sunlight
2. Ventilate the battery whilst charging
3. Prevent water and excessive dust from contaminating the components

Wiring

The electrical current transported through the system should technically never exceed 1.6 Amp hours, which is 20W. Due to heat and environmental strain considering the unit will be outside, the unit used for testing incorporated 1.5 mm (standard domestic light) wiring cable where needed. Should the system be expanded suitable wiring upgrades will need to be considered.

Construction:

To assemble follow the wiring diagram below:

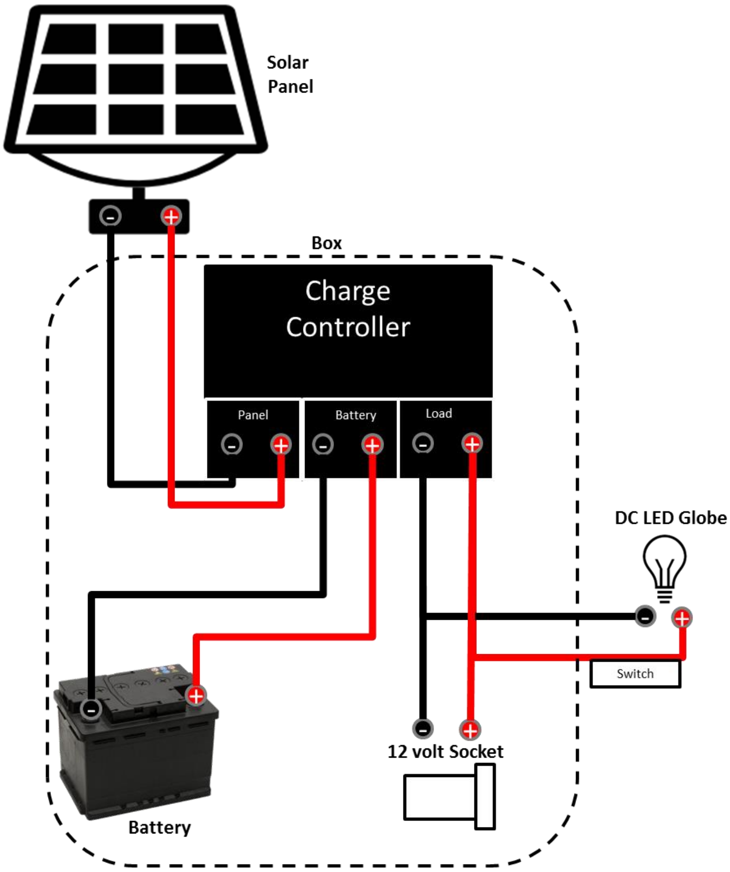

Figure 1: Solar Wire Diagram

More information:

Why a charge controller?

The charge controller [most brands] also protect the battery from under voltage. In case a load is connected to the battery unintentionally or left on.

As well as preventing over voltage most controllers follow a three phrase charging cycle which further promotes longer battery life.

Aside from a few chargers with advanced algorithmic estimators, most chargers cannot determine the size of the battery connected. They can however determine the voltage of the battery which they use as an indicator to determine how much charge the battery contains. To do this they treat the battery like a bottle of water. Where the pressure = voltage and current = rate of flow of water. As we fill the bottle with water the pressure changes and as the pressure increases we know the bottle is technically full. Adding more water will increase the pressure which will result in the battery/bottle of water distorting.

Battery:

The battery stores power converted by the panel, and provides power back to the charge controller when the panel cannot provide sufficient power to support the load connected to it. Batteries come in a variety of sizes and designs. The core structure of batteries are very similar however basic elements of the design are manipulated to accommodate different purposes.

A standard car battery is not designed to deliver power for prolonged periods of time. It is designed to deliver power in a short time to start/crank an engine. Due to its intended purpose it was not designed to discharge past 50-80% of its capacity continously. As such not adequate for our requirements.

An alarm battery or marine type lead acid battery (often referred to unofficially and incorrectly as a deep cycle*more on this later), is generally designed to provide power over a prolonged period of time. As such more suited to our needs. Bear in mind however that whilst these type of batteries are used to provide power over a prolonged period of time. To prolong battery life an accepted rule of thumb is not to discharge this type of battery past 50% . Lead- Acid batteries or Gel batteries are the most common batteries used in this type.

True deep cycle batteries are meant to be discharged around 80% of their capacity. They are generally expensive due to the inherent cost of these batteries as a result of more advanced materials being required. They are not as common in smaller real world use applications.

Inverter:

The purpose of an inverter is to convert DC or direct current provided by a battery or solar panel into AC or Alternate Current similar to a household plug point. (please bear in mind that configurations of household voltages and pins differ between regions of the world.

Smaller inverters have cigarette lighter connectors to connect to the car whilst longer inverters have direct to battery connections.

In our setup an inverter is not used, as the globe we use is a DC globe which can absorb the power direct from the battery without modification. Had we used an AC 220V household globe an inverter would be required to convert the Battery DC power into a format the AC 220V globe could use.

In testing the setup proposed was fitted with a 75W inverter to connect small household appliances like cellphone chargers and a radio. The average consumption of these devices was 15w which allowed us to power the device for +- 3 hours.

Prototype pictures:

Figure 2: Complete wiring

Figure 3: Testing

Figure 4: Assembled