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Solar Powered Portable Charging Unit as Emergency Response for Disaster Prone Areas

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Abstract— **Long term power cut off situation during and after any natural calamity can bring unbearable sufferings to people. Emergency situations are taken care of by several relief activities. But providing emergency electric power is still very rare or selectively available to medical emergencies only and that is too, solely based on electric generators burning expensive diesel fuel. Application of renewable energy, specifically solar energy in a portable way, can be an efficient, cost effective, pollution free sustainable solution in such cases of emergency response. This paper presents a solar powered battery charging unit that can be carried to anywhere and electric power can be fetched during day time and after dark for charging and powering up our essential electronic appliances like mobile, Wi-Fi router, low powered fan, light etc. Here we have developed and tested solar powered portable charging unit or emergency electric power provider unit for domestic use as well as for disaster prone areas for emergency response.**

Keywords—Solar Charger;Emergency Electricity; Portable Charging Unit; Emergency Response.

I. INTRODUCTION

People living in rural areas of Bangladesh faces frequent power cut off problems mostly known as load shedding due to the fact that, the production does not meet the demand. In developing countries like us power failure is a common thing especially in rural areas or in case when any natural disaster takes place then the power cut off situation can continue for 3-4 days, even a week or more. People living in coastal areas of Bangladesh faces disasters such as flood, hurricane, tornado and after effects of those more severely than people living in other part around the country. After any calamity; failure of utility grid is very common. Moreover, very small scale seasonal storm, heavy rainfall, flood or strong wind also plays a vital role for long term power cut offs. After disaster, many organizations conduct relief work by providing food or other lifesaving products but there is no way of providing electricity to general people to meet up their urgent need of electric power in a sustainable way; other than renewable energy.

Renewable energy is the most talked research topic of contemporary research arena. Among all the renewable energy sources, solar energy is the ancient, mostly harvested [1] and used technology as the source is abandoned and the harvesting technology is simple but effective. Renewable energy does not contribute to global warming and that is the point for which it is getting more attention day by day. As an unlimited, harmless source of energy renewable energy is becoming a new hub of newer applications in our daily life. Our present life is now full of gadgets such as mobile phone, laptop etc. and to run those we cannot think of power failure for long. This research aims to help powering our most essential equipment in emergency situations through solar power harvesting. Here is an idea to develop a solar powered portable charging unit that can charge emergency electric devices at an adjustable voltage range, directly by converting solar energy into electricity and simultaneously, can store charge to a rechargeable Li-ion battery which can further be used to charge different electric appliances of our daily necessity.

II. Related Research

Similar types of studies were found done earlier. After any natural disaster, a number of injured people need treatment and care. Immediate supply of oxygen can reduce the rate of harm [2,3]. Solar power was planned to be harvested and then stored in energy storage battery and later to be used to charge both 12V AC power for emergency equipment such as miniature PSA oxygen concentrator and 5V USB for electronic equipment (mobile phone, GPS device, rechargeable light, etc.). The circuit includes complex PWM (Pulse-Width Modulation) charging, overcharging protection, over-discharging protection and over-current protection and also the fast and safe charging of energy storage battery; to be used at a large aspect [4].

Ramly et al. [5] have suggested Emergency Portable Solar Power Supply (EPSPS) which provides electric power to various loads (both AC and DC) by harvesting and storing solar energy. To ensure remote monitoring of the system it includes an Arduino Uno with Bluetooth module. EPSPS can supply 100W of AC/DC power at 12V and can run for 2days without charging if the battery gets charged once for at least 6 hours.

The developed system in "Multiple Chargers with Adjustable Voltage Using Solar Panel" [6] contains, solar panel fetching solar energy and then storing it in a rechargeable battery. Later the rechargeable battery can charge batteries and devices of variable voltage requirement. Suppose it can charge cellphone batteries of 5V and 3.7V and pencil batteries ranging from 3-9V. This charger might also come in handy to charge other type of batteries such as automotive batteries and IPS.

III. System Designing and Developement

3.1 Methodology

Solar charger unit operates on the principle that the charge controller will produce the constant voltage from solar panel and will be able to charge devices on demand by adjusting output voltage to desired range from (3V-12V) using converters with display while simultaneously storing charge to a LiFePo4 battery at 12 V. The panel can directly be connected to converters without connecting to battery or controller to have voltage above than 12V.

3.2 System sizing

a) Load Profile

Type and usage of electric appliances varies depending on different time or part of the day. For example lamps would only be used during night time after the sun sets but table fans may run both during day time as well as night. Not only this, but the battery backup calculation can also be modified to get more specific backup times, reducing battery expenses; since during the night time, not every appliance would run for same backup hours. Considering those facts load profile has been calculated in two ways to obtain a concise system, reducing cost.

TABLE I. Direct Power Consumption During Sun Hour

Item	Wattage w	Quantity	Hours	Total Wh
Smartphone	10	1	2	20
Button phone	7	1	1	7
Small Fan	5	1	1	5
Router	8	1	0.5	4
Total power W	30	Total power consumed per day Wh/d = 36		

TABLE II. Power Requirement For Battery Backup Or Nighttime Use

Item	Wattage w	Quantity	Hours	Total Wh
Smartphone	10	1	2	20

Button phone	7	1	1	7
Table fan	5	1	9	45
Lamp	3	2	5	30
Total power W	28	Total power consumed per day Wh/d		= 102

Table I and II, shows types of items and quantity of those along with individual wattage ratings.

b) Battery

Most of the electronics of present time use rechargeable batteries, in fact some are designed to use no other batteries than rechargeable batteries specifically [6]. Among different types of rechargeable batteries, the most popular ones are lead-acid, lithium-ion and nickel-cadmium. Lead-acid batteries are widely available, comparatively cheap but not suitable for our portable solar charger unit because of their heavy weight, liquid electrolyte and frequent maintenance requirement.

Lithium-ion batteries are expensive but yet it has been chosen to be used in this research because of the following facts:

- Dry, portable and maintenance-free electrolyte
- Light weight
- Small sized
- Longer lifespan
- Can be discharged up to 100% without damaging the cells
- Can be left in a state of low charge for a long period [7].

The system would be used as emergency response which is indeterminate and because of that the batteries could left uncharged and unused for indefinite period; thus batteries should be maintenance –free, long lasting. Again the system should be of lightweight to carry, so the electrolyte of the battery should must be dry type to ensure its portability. Keeping in mind the above facts, the type of battery selected to be used here is Li-ion or to be more specific LiFePo4, battery.

The equation used here for determining minimum battery capacity for average 6 hours of backup [7]:

Q = (Eday * DoA * BTM) / (DoD * CE * SV)

- Q is the Minimum battery capacity required (in Ah),
- Eday is the Average daily energy target (in Wh)= 102 Wh (From table:2)
- DoA is the Days of Autonomy =1, (Assumed)
- BTM is the Battery Temperature Multiplier =1 (Negligible)
- DoD is the permissible depth of battery discharge = 80%
- CE (Cable Efficiency) denotes the losses in the cables =1 (Assumed)
- SV is the System Voltage =12V (for small system)

Thus, battery capacity required,

$$Q = \frac{102 \times 1 \times 1}{0.8 \times 1 \times 12} = 10.625 \cong 11Ah$$

As Li-ion battery of 11Ah was not available so a little higher capacity of 14Ah LiFePo4 battery was chosen for expected backup.

c) Charge Controller

A charge controller performs regulation of voltage and current in between solar array and battery, to keep batteries safe from overcharging and prevent deep discharging [8]. By controlling directly the state of charge of the battery, charge controller can extend the lifetime of the battery.

d) Solar Panel sizing

Solar energy is the richest among all other renewable sources. A solar cell, also called photovoltaic cell, is thus a device that directly converts solar radiation into usable electricity. It is based on the photoelectric (or photovoltaic) effect [1]. Photovoltaic cells are generally constructed with mono or poly crystalline silicon, arranged in a grid type pattern forming the surface of solar panel [9].

Solar panel should have enough capacity so that it can charge up 14Ah battery and be able to power necessary electronics, all together simultaneously during day time. Required total power of the panel can be figured out from table I and II,

Direct Power consumption during sun hour = *36 Wh*

Power Requirement for battery charging = $11\ Ah \times 12\ V = 132\ Wh$

Total power needed to be generated per day = *168 Wh*

Total power needed to be generated per hour $= (168\ Wh)/(Avg\ Sun\ Hr) = (168\ Wh)/(8\ h) = 21\ W$

Total power needed to be generated should be higher than total power required, compensating system inefficiencies. A multiplication factor of 1.3 had been used, considering the stated fact [5].

Thus total power of solar panel required $= 21\ W \times 1.3 = 27.3\ W \cong 30\ W$.

Thus a 12V, 30 W solar panel was chosen for the system.

Panel specifications:

Unit	Rated amount
Dimension(mm)	660*360*25
Rated Maximum Power (Pmax)	30 W
Rated Voltage (Vmp)	17.8 V
Rated Current (Imp)	1.69 A
Open-Circuit Voltage (Voc)	21.8 V
Short-Circuit Current (Isc)	1.82 A
Maximum System Voltage	1000 V
Weight (kg)	2.5 kg

e) Fixed output and regulated output terminal

The controller has only two DC load terminal. For convenience and fast charging of mobile or other USB devices the setup includes a car mobile charger USB hub. Any other USB device can also be connected and powered through that hub. Instead of that car charger, system includes voltage regulator circuit with an LED display by which a range of load devices (ex. Lamp, fan, Wi-Fi router) of variable voltage requirement (up to 20V) can be charged on demand. Fig.1. shows system block diagram.

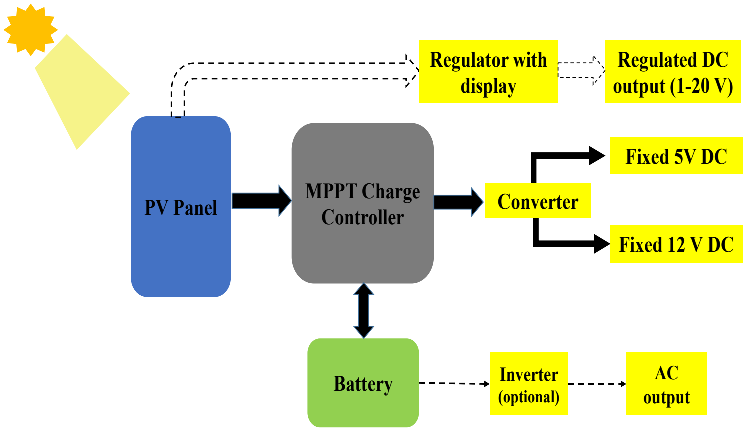

Fig. 1. System block diagram with possible output ports

3.3 Prototype development and testing

Fig. 2 shows general architectural view of the prototype of solar powered portable charging unit (SPPCU). It is a wooden case/ box with solar panel mounted as its upper cover or lid, and the inner space is partitioned into small & medium crates to fit other system equipment like battery, controller and converter with USB hub, inside it.

Fig. 2. External view (left) [10] and internal view with battery and controller (right) of Prototype

Fig. 3. Powering several devices at their required voltage; Powering fan (left); Charging smart phone at 12V and feature phone at 5.3V (middle); Powering router at 9V(right) [10]

Fig. 3 shows that, the system is capable enough to power a no. of DC appliances, operating on different levels of input voltage range such as smart phone, feature phone, small fan and Wi-Fi router etc.

IV. Result and Analysis

4.1 Analysis of data from solar panel without load

This analysis reveals the performance of the solar panel installed in the system. The measurements of voltage and current were taken at 12 different times of the day (from 6am-5pm), for two consecutive days. Fig. 4 shows panel voltage without load condition for 12 hours of a day. From the graph it's clear that, panel shows almost steady voltage on the first half with a peak in voltage at 12 pm (for day 1 only) and degrades during second half. The feature is almost same for the second day of experiment with some exceptions due to drastic change in solar insolation. On the other hand, the graph shown on fig. 5 is drawn based on the measurements of current found during those two days of previous experimental set up. Current obtained remains very low around early morning and after 9 am the bar raises and continues to raise up to 12pm/1pm. After that the bars go down steadily with an exception at 3pm on day 2 due to cloudy weather. Similar feature of lower voltage level can also be seen on voltage graph on the 2nd day at 3pm, due to same cloudy weather condition.

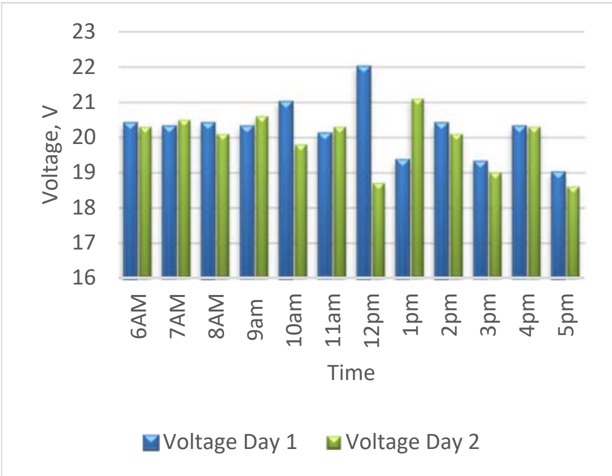

Fig. 4. Voltage from solar panel

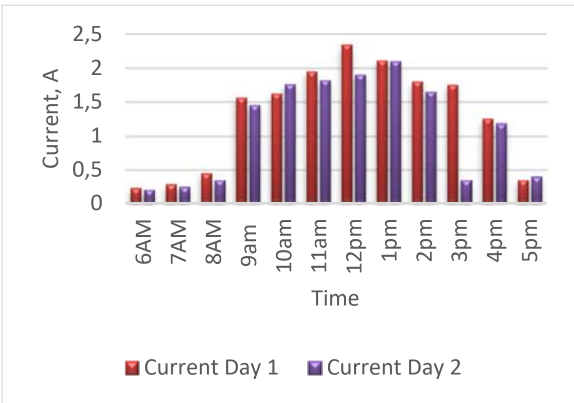

Fig. 5. Current from solar panel

From the graphs, it was easy to assume the average panel characteristic i.e., voltage and current from panel on different time and on different solar insolation, of a day. Moreover, data taken during a wide range of time (9am-5pm), on two alternate days; was good enough to have consistent assumption on average daily sun hour. Studying the experimental data as shown in fig. 5, avg. sun hour was been taken as 8 hours per day.

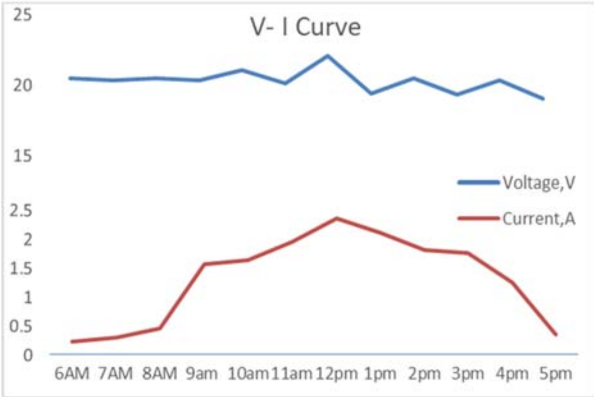

Fig. 6. I-V curve of solar panel for day 1

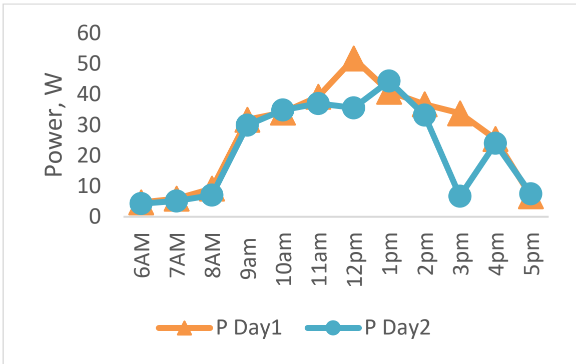

Fig. 7. Power obtained from solar panel on daily basis

Fig. 6 shows I-V curve of the solar panel from 6am to 5pm, for day 1. And fig. 7 shows significant variation in solar power curve with variation in solar insolation due to sunny or cloudy weather condition on day 1 and day 2.

4.2 Battery charging data analysis

a) Battery without load

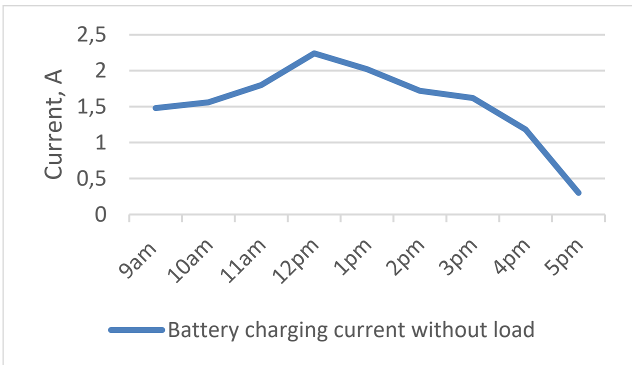

Fig. 8. Battery charging current without load

The rate of charging current received by battery in no load condition is shown in fig. 8. Relative analysis with panel current (graph of fig. 5 and fig. 6 shows that during no load condition battery receives almost all the current coming from panel with a consistent and tiny system loss of around 0.09A (from table III). Comparative study is shown below in table III.

TABLE III. BATTERY CHARGING CURRENT WITH SYSTEM LOSS

Time	Panel Current, A	Battery charging current without load, A	System loss, A
9am	1.56	1.48	0.08
10am	1.62	1.56	0.06
11am	1.95	1.8	0.15
12pm	2.35	2.24	0.11
1pm	2.11	2.02	0.09
2pm	1.8	1.72	0.08
3pm	1.75	1.62	0.13
4pm	1.25	1.18	0.07
5pm	0.35	0.3	0.05
		Avg. battery charging current = 1.55 A	Avg. system loss= 0.09

From table III, average battery charging current was found to be 1.55A during no load condition. That means, our 14 Ah battery when charging in no load condition, will get average of 1.55A current. With that rate, it will take *(14Ah÷1.55)= 9.05* h to get fully charged on average sunny weather. While practically our battery took roughly, 10h to charge from 0%-100%. The difference estimated and practical time limit may have caused due to the variation in solar insolation.

b) Battery charging with load

The testing and validation of the devoloped system was done by powering up and charging several electrical appliances such as smart phone, feature phone, fan and even router. All the appliances found to be functioning and taking charge smoothly. To raise the level of charge of a smartphone battery of 4500mAh, from 2% to 100%, the system took approximately 2hr and 5 min.

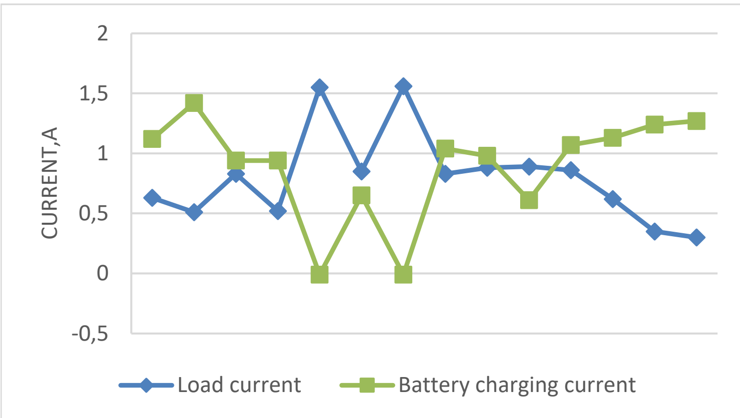

Fig. 9. Load current and battery charging current

Some analysis were also carried out to observe, the way the system responses when both load and storage battery remains connected at a time for charging during day time. For example, smartphone and storage battery left for charging together under sunlight. Since the system was designed considering the fact that, the charging unit will be able to charge load device and storage battery together. Graph on fig. 9 features battery charging current with load condition, together with current drop at the load. Where the green and blue curves show battery charging current and load current respectively. The data readings were taken while a smart phone was being charged, up to a certain level [fig.10]. Curves found to show inverse relationship between them, all through the experiment with negligible exception on some points.

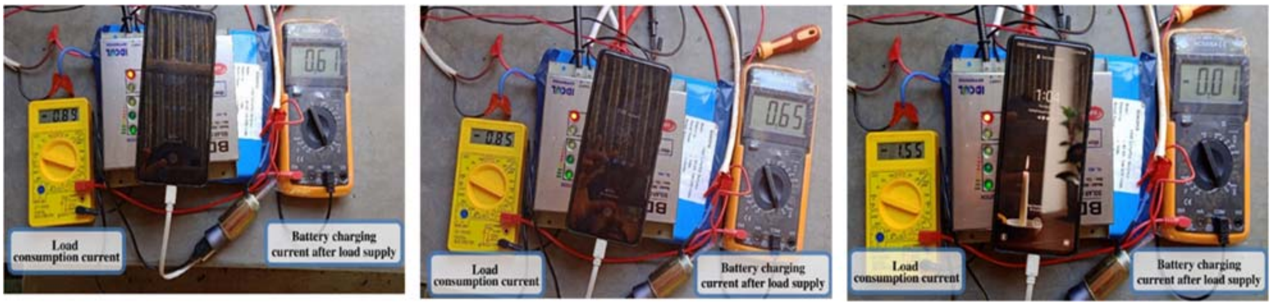

Fig. 10. Load current and battery charging current on two meters

The storage battery was tested to charge smart phone and other DC appliances without sunlight, during night. The powering up and charging process found fast and efficient enough.

V. Conclusion

Analyzing all the studies and results shown in the previous chapters it can be concluded that the system prototype developed in this research, functions well and meets the purpose of emergency power provider during power failure. Such tiny set of emergency power provider can be truly helpful for domestic use or for people over disaster prone areas.

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