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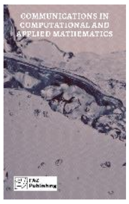

A Hybrid Solar-Battery-Supercapacitor Based Camping Lamp

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Abstract: Lighting is an essential and insufficient lighting will make us difficult to see things clearly and performing almost all our daily activities. There will be a problem for activities like camping or hiking because there is no electricity and a camping lamp usually used to provide light. Previous product of camping lamp use only rechargeable battery as the supply and it is unconvincing to use the camping lamp for a long time as it only stays on for a few days. A camping lamp that can be charged by exposing to the sunlight can be the solution to overcome this problem. This study is enhancing the features of camping lamp using solar energy as the source to recharge the energy storage devices. There are two types of energy storage devices namely rechargeable battery and supercapacitor that function as the backup charging system. The supercapacitor harvest solar energy from the camping lamp itself so that the product can be recharge when there is no sustainable sunlight. The product will give a huge benefit to anyone who love to do outdoor activity.

Keywords: Camping lamp, solar, supercapacitor, backup charging

1. Introduction

Nowadays, outdoor activity such as camping and hiking have become a common hobby. Usually camper or hiker travel during daytime as sunlight provide clear vision. Camping or hiking usually can take days or weeks as its needed them to stop continuing their journey and camp at certain location at night due to poor or lack of durable light conditions. Camping lamp is needed to provide light and it is essential to use light sources which have outstanding reliability and maintenance-free properties. Solar energy can be used as a source like many application such as calculator, electrical cars, solar lamp in the street and lamp for indoor lighting. However only few product that using solar technology integrated with light emitting diode (LED) lamp for a portable solar lamp [1].

Existing camping lamp only used rechargeable battery as a source to the load and it usually cannot last in longer time.
Normally, battery used as the energy storage system (ESS) for the photovoltaic lighting system. Battery is one of the most cost-effective energy storage. Battery function as a long term energy storage device and maximize the efficient use of renewable energy sources [2]. Another option of ESS is by applying supercapacitor. A supercapacitor can operate faster to accept and deliver charges faster than a typical battery. Typically, a supercapacitor is applied in application that requires rapid charge and discharge cycle rather than long term energy storage. The advantages of supercapacitor are its high specific energy, long life cycle, large capacitance and low series resistance [3-4]. In the supercapacitor, energy is stored electrostatically on the surface of the material and does not involve chemical reactions [5]. The supercapacitor can be charged quickly, leading to a very high power density, and do not lose their storage capabilities over time [5]. However supercapacitor discharge rate is fast and only use to deliver short term power [4].

This study focused on the development of a hybrid solar-battery-supercapacitor based camping lamp. A standalone photovoltaic lighting system as a source for the camping lamp while the battery and supercapacitor as energy storage devices. The camping lamp can be charge during the day journey and can be directly use at night. The lighting system is using LED to provide medium lumen for low consumption power. This system has been a good way in harvesting solar energy for lighting purpose and reliable because it require

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little or free maintenance. The battery and supercapacitor can be used compliments each other disadvantages in enhancing the capabilities of the camping lamp.

2. Research Methodology

In this study, the solar is the main generation source while the supercapacitor and battery acts as storage devices for the system. There are primary and secondary solar. The primary solar is the main source which it used to charge the battery directly. The secondary solar is the backup generation source which used to charge the supercapacitor. The LED acts as a load and also as a source to the secondary solar. Fig. 1 shows the block diagram configuration for this camping lamp.

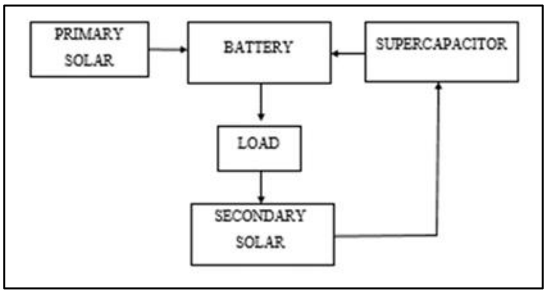

Fig. 1 Block diagram of hybrid solar-battery-supercapacitor based camping lamp

The workflow of hybrid solar-battery-supercapacitor based camping lamp starts by switching the toggle switch on. The load of LED will light up and at the same time the secondary solar will absorbed the light from the LED and the output will charge the supercapacitor. The first condition is to check either LED's light is dim and it can be charge by using primary solar if there is sustainable sunlight or just by using the available energy stored inside the supercapacitor. The process is then repeated if the battery is fully charge and the hybrid solar-battery-supercapacitor based camping lamp is ready to be used.

There are two main circuit in this research namely primary solar circuit and secondary solar circuit. The primary solar circuit consist of two main components of 5V solar cell and 3.3 NiCd rechargeable battery. A 1N4007 diode is connected in series with the solar cell to avoid any overvoltage to the battery. The schematic diagram for the primary solar circuit as shown in Fig. 2.

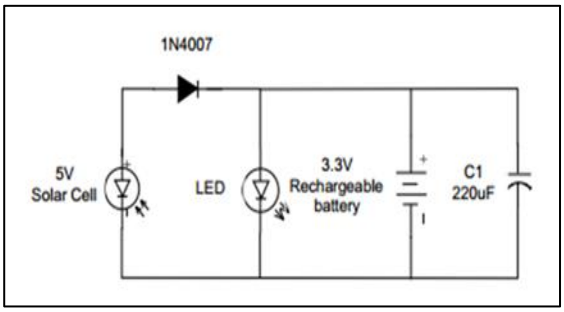

Fig. 2: Schematic diagram for Primary Solar Circuit

For the secondary solar circuit, 5 V solar cell, 2.7 V 400 F supercapacitor and IC QX5252 were used. The output from the solar cell is adjusted by the distance range from 40 mm to 60 mm of the solar cell from the light source. Due to the rating of supercapacitor that is only 2.7V a limiter diode need to be put in series with the solar cell to avoid any overvoltage to the supercapacitor. Fig. 3 shows the distance of the LED to the secondary solar cell. Fig. 4 shows the circuit diagram of secondary solar circuit.

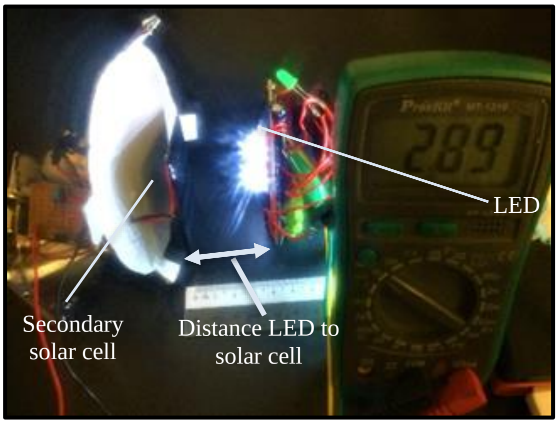

Fig. 3 Distance of the LED to the secondary solar cell

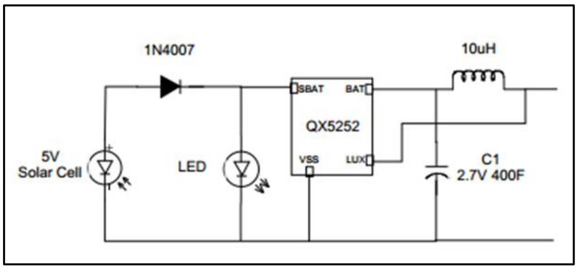

Fig. 4 Schematic diagram for Secondary Solar Circuit

3. Results and Discussion

The primary solar was used to charge the 3.3 V 300 maH battery that acts as the primary energy storage for supplying the load. The test was done at 11A.M until 1.40P.M and the irradiance of the day is bright. The initial voltage of the battery tested start at 0.8V. Fig 4 shows the voltage of battery charging with time.

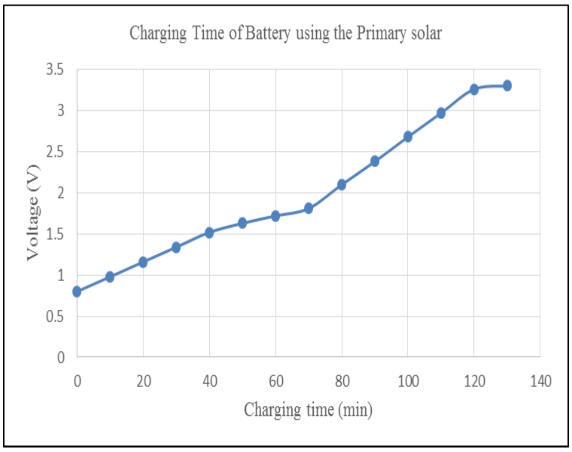

Fig. 4 Voltage of battery charging with time

From Fig. 4, the charging graph of battery rise gradually but is not in exact linear due to small current generated from the primary solar resulting slow chemical reaction of the battery. NiCd rechargeable battery is suitable for a slow rate charging to make sure longer life cycle of the battery.

The discharging time of the battery was applied to light up the load at night or dark time. The test was done similar to the possible duration of the load can be used which was 12 hours. Fig 5 shows the voltage of battery discharging with time.

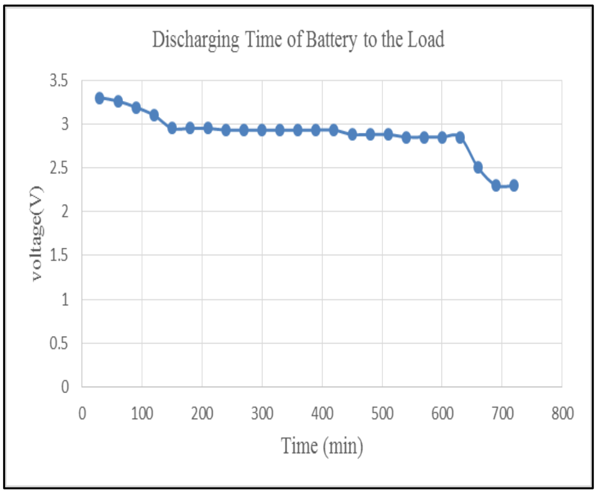

Fig. 5 Voltage of battery discharging with time

Based on Fig. 5 it shows that the voltage of the battery was discharging with time. As the voltage decrease, the lamp intensity increase as the battery charge up the lamp by discharging it voltage. The lamp intensity also decrease at certain time as the voltage from the battery decrease as it not enough to light up the lamp.

The secondary solar receive its source from the LED that had been light up from the primary circuit. The distance between the LED to the secondary solar cell was varied to test the output voltage and current of the secondary solar cell. Table 1 shows the distance between the LED and the output of the secondary solar cell.

Table 1 Distance between LED and output of secondary solar cell.

Distance of LED to the secondary solar panel (mm)	Output voltage (V)	Output current (mA)
40	2.89	110
50	2.72	116
60	2.56	121

From Table 1, the output of the solar panel varies directly proportional to the distance of the LED to the solar cell. The test was done in completely dark room so any external light source such as reflected light was neglected. The output will varies when external light source is available so a limiting resistor is put in series to solar panel. Due to limitation of light that can be captured by the solar panel, the distance of 60 mm that produce 2.56 V and 121 mA was chosen for the finalization of the product. The decision was made to match the voltage rating of supercapacitor.

Based on the output produce from the secondary solar panel, supercapacitor was charged and duration for the supercapacitor to fully charge was recorded. The initial voltage of the supercapacitor start at 0.82V. The duration for the supercapacitor to fully charge was 80 minutes. Fig. 6 shows the voltage of charging supercapacitor with time.

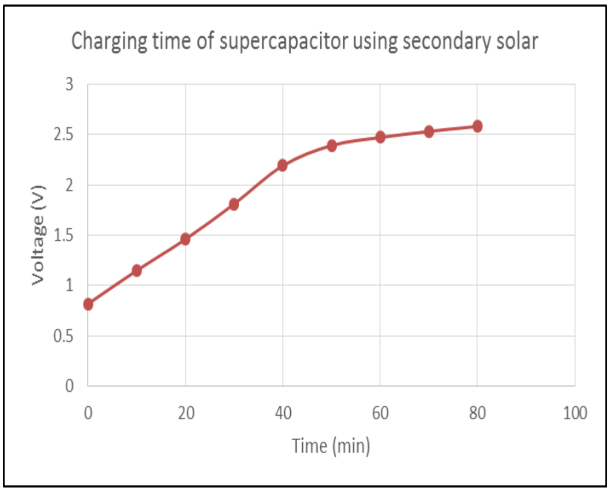

Fig. 6 Voltage of charging supercapacitor with time

From Fig. 6, the secondary solar was supplying 2.56 V 121 mA and charging the supercapacitor from 0 to 40 minutes at average of 0.033 V/min. The charging rate gradually decrease after reached 2.19V due to the supercapacitor need less current to reach the rated voltage. Supercapacitor has the characteristic as it can overflow charging phase so there is no overcharging occur as long as the charging voltage does not surpass the rated voltage. This give a good reason to use supercapacitor as the energy storage device at secondary solar circuit due to the lamp will be used for hours at night. As long as the lamp is turn on the supercapacitor will overflow the excessive charge without effecting its performance.

Next, the discharging time of supercapacitor was recorded when the battery voltage was at 0.8V and the supercapacitor is fully charge at 2.56V. As the current discharge from the supercapacitor controlled by the QX5252 IC, the constant current flow to the NiCd battery is at 200mA. Fig. 7 shows the voltage of discharging supercapacitor and battery charging with time.

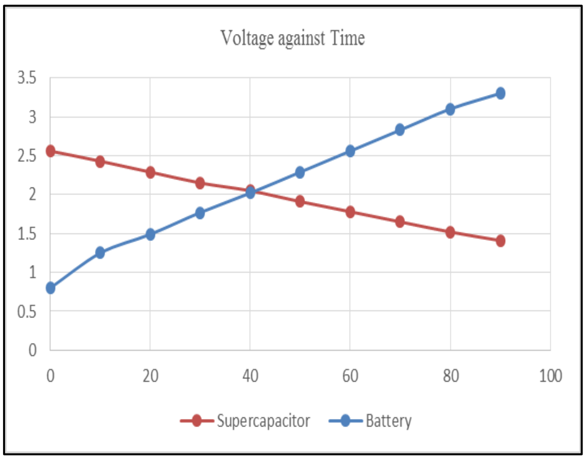

Fig.7 Voltage of discharging and charging battery with time

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From Fig. 7, the duration of the rechargeable battery to fully charge from a full discharge state takes about 90 minutes. As the charging current is constant, the charging rate as volt/time increase linearly. The voltage rating of supercapacitor is only at 2.7V but the 20uF filter capacitor act as to store voltage to reach 3.3V until battery is fully charge. Adapting supercapacitor as the backup energy storage device to the secondary solar circuit is convincing as it can store high amount of energy with good characteristics of charging and discharging.

4. Conclusion

A hybrid solar-battery supercapacitor-based camping lamp has been successfully designed in this study. The primary solar charge up the battery and the battery is successfully discharged to light up the LED. This LED acts a load and source to secondary solar. The supercapacitor can charged and discharged, thus the camping lamp is ready to be used. The generation of power from secondary solar as a backup system to store energy using the supercapacitor as energy storage device helps when there is no sustainable sunlight. For future enhancement, several improvements can be made to this project. A low power consumption display can be added to this project as normal display device need higher voltage. Next, protection circuit can be added to protect the energy storage device from overcharging. Lastly, the design of the project could be alter to smaller size and more durable towards shock and humid.

Acknowledgement

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