UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FAKULTI KEJURUTERAAN ELEKTRIK

SOLAR HARVEST AND SUPERCAPACITOR FOR POWER STORAGE IN LOW POWER DEVICE

Muhammad Syahmi Bin Ahmad Johari

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MUHAMMAD SYAHMI BIN AHMAD JOHARI

A project report submitted in partial fulfillment of the requirement for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I hereby declare that I have read through this report entitle ” Solar Harvest and Supercapacitor For Power Storage In Low Power Device” and found that is comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)

Signature : ………..………………………………..

Name : WAN MOHD BUKHARI BIN WAN DAUD

Date :

I hereby declare this report entitle “Solar Harvest and Supercapacitor for Power Storage in Low Power Device” is the results of my own research except as cited in the references. The report has not been accepted for any degree and it is not concurrently submitted in candidature of any degree.

Signature : ………..………………………………..

Name : MUHAMMAD SYAHMI BIN AHMAD JOHARI

Date :

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ABSTRACT

Solar energy and photovoltaic (PV) was known as attractive solution as alternative power generation source that is sustainable. Despite of that, biggest limitation of solar energy is its avaibility. The reasons are the clouds and nightfall interrupt collection of energy, thus limit time and lack of efficient for solar to charge batteries during this situation. The purpose of this study is implementation of a solar energy using supercapacitor for power storage in application low power circuit devices. A supecapacitor is an energy storage device utilizes high surface area carbon to deliver much higher energy density than conventional capacitors. The supercapacitor balancing circuit use in this device as charging circuit and balance the voltage between two supercapacitors and thus protect them from overvoltage. In this study solar device performs maximum power solar energy collection from balancing circuit with under various light conditions, with high efficiency and low energy cost without using mechanical solar tracker. Much attention has been given to identify the power use in circuit component. The result shows that system maintains averagely 10V to charge the battery in any weather condition except nightfall. This system achieves low power consumption which maintained operation efficiency and reduce cost operation of solar energy.

ABSTRAK

Tenaga solar dan fotovoltaik (PV) adalah salah satu jalan penyelesaian yang menarik sebagai sumber alternatif. Walaubagaimanapun, had terbesar tenaga solar adalah kadar pencahayaan matahari. Ini disebabkan, cahaya matahari adalah terhad apabila berlaku perubahan cuaca seperti mendung dan hujan. Tujuan kajian ini melakasanakan sistem tenaga solar menggunakan superkapasitor sebagai simpanan dalam aplikasi voltan rendah. Superkapasitor adalah alat simpanan tenaga menggunakan karbon berkepadatan tinggi berbanding kapasitor konvensional. Litar pengimbang superperkapasitor digunakan bagi mengimbangi voltan di antara dua superkapasitor ketika dicaj dan melindungi litar daripada voltan terlampau. Dalam kajian ini, peranti tenaga solar melakukan pengumpulan tenaga secara optimum melalui litar pengimbang superperkapasitor di bawah pelbagai keadaan cuaca, dengan kecekapan yang tinggi dan kos tenaga yang rendah tanpa menggunakan tracker solar mekanikal. Perhatian yang lebih telah diberikan kepada mengenal pasti penggunaan kuasa dalam komponen litar. Hasilnya menunjukkan bahawa sistem mengekalkan 10V secara purata untuk mengecas bateri di bawah pelbagai keadaan cuaca. Sistem ini berjaya mencapai penggunaan tenaga yang rendah yang mengekalkan kecekapan operasi dan mengurangkan kos operasi tenaga solar.

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LIST OF SYMBOLS

Ω	-	Ohm
C	-	Capacitor
V	-	Volt
h	-	hour
mV	-	millivolt
A	-	Ampere
μV	-	microvolt
F	-	Farad
μF	-	microfarad
mA	-	milliampere
%	-	Percent

LIST OF ABBREVIATIONS

PV	-	Photovoltaic
LV	-	Low voltage
C	-	Capacitance
LV	-	Low Voltage
R	-	Resistance

CHAPTER 1

INTRODUCTION

1.1 Project Background

Solar power is renewable source of energy, which has become increasingly popular in modern times. There are lot of advantages over non renewable energy sources such as coal, oil and nuclear energy. It is non-polluting, reliable and can produce energy anywhere that there is sun shining, so its resources are not going to run out anytime soon. It also has advantages over other renewable energy sources, including wind and hydro power. Solar power is generated using solar panels, which do not require any major mechanical parts such as wind turbines. Energy storage is the key component in solar energy for creating sustainable energy systems. Currently, the dominating energy storage device is battery, particularly the lead-acid battery. The charge and discharge process in batteries is a slow process and can degrade the chemical compounds inside the battery over time. As a result, batteries have a low power density and lose their ability to retain energy throughout their lifetime due to material damage [1]. The supercapacitor uses a different storage mechanism. In the supercapacitor, energy is stored electrostatically on the surface of the material, and does not involve chemical reactions. Given their fundamental mechanism, supercapacitors can be charged quickly, leading to a very high power density, and do not lose their storage capabilities over time. Supercapacitors can last for millions of charge and discharge cycles without losing energy storage capability [2]. The battery behave like a slow and steady energy supplier for large energy demands, and the supercapacitor that charge and discharge quickly for low energy demands.

1.2 Project Motivation

In this study supercapacitors are used to store temporary energy to charge battery. They are attractive as they have a higher power density than batteries, do not require special circuitry, and have a long operational lifetime which is usually considered to be not effect to the number of charge and discharge cycles [2].

Many research efforts into the use of supercapacitors in second choice for power storage in low power device. From previous work the progress in low-power design, the research has greatly reduced the size and the power consumption in low power device, and the design of these systems can improve by use correct energy harvesting techniques and store the energy in supercapacitor. Nowadays, small solar panels suffice to ensure continued circuit operation, and several PV harvesting circuits have been recently proposed for low power device [3], [4].

Other works suggest using maximum-power-point tracking (MPPT) techniques in solar harvest for optimum supercapacitor charging. It stated that the output characteristics of a PV array vary nonlinearly when temperature or sun light conditions change. Therefore, maximum-power-point tracking (MPPT) techniques are use for adjusting the operating point of the solar panel in order to obtain the maximum output power from the PV module. So far, MPPT methods have been in small-scale PV power systems, usually without digital controllers. They are less accurate, but they are cheaper with advantageous cost efficiency in PV applications below 50 W for charging supercapacitor [5], [6].

1.3 Problem Statement

The biggest limitation of solar energy is sunlight avaibility. The reasons are the clouds and nightfall interrupt collection of energy, thus limit time and lack of efficient for solar to charge batteries during this situation. Solar power is used to charge batteries so that solar powered devices can be used at night or used in absent of light. The absent or less intensity sunlight prevent the solar energy charging the battery because during that situation the power collected not meet the charging voltage of battery.

1.4 Objective

The aim of this study is develop prototype a solar energy using supercapacitor for power storage in application low power circuit devices.

The objectives of this study are:

i. To design solar harvest using supercapacitor for power storage in low power device.

ii. To build a prototype solar harvest using supercapacitor for power storage in low power device.

iii. To analyze the performance of the design hycircuit by testing under various charging and discharging conditions.

1.5 Scope

The scope of this project is to study, understand and investigate the characteristic of supercapacitor and its advantage over commonly use. Hence the research is target to design energy using supercapacitor for power storage in application low power circuit devices. Then, the development of hardware prototype is implemented. The supercapacitor balancing circuit use in this device as charging circuit and balance the voltage between two supercapacitors and thus protect them from overvoltage. In this study solar device performs maximum power solar energy collection from balancing circuit with under various light conditions,. The performance of the circuit tested under various charging and discharging conditions. In addition, this prototype will be build based on simulation and testing that consist component of solar panel, supercapacitor and embedded system. The developed hardware will be test and analyze in term of it functionality.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

All the related topics and studies will be included in this chapter. In previous research and studies, all the information related to theory and characteristic of supercapacitor and photovoltaic have been collected either from IEEE journals, thesis, book and website.

Section 2.1.1 and 2.1.2 describe the theory and principles that involved in this project. Lastly Section 2.2 reviews the previous related work to this topic .

2.1.1 Photovoltaic

Photovoltaic is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductor that exhibit the photovoltaic effect. Material presently used for photovoltaic includes monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride and copper indium gallium selenide/sulfide.Open circuit voltage (Voc), is voltage developed as the terminals are isolated. The short circuit current (Isc), is current drawn as terminals are connected or with zero load resistance.

2.1.1.1 Limit in Photovoltaic Efficiency

The steady evolutionary progress of the PV industry is the result of increase in automation of engenderment of thin film solar cells with incremented efficiency and lower costs. The decider for revolutionizing breakthroughs in the PV industry is sometimes halted by the advancements in the PV materials and manufacturing technology leading to amendments in the cost competitiveness and the expansion of the PV market. By shattering the old limits of efficiency and cost by bringing about innovations by exploiting incipient understanding of physics and material science will become an expeditious paced revolution [7].

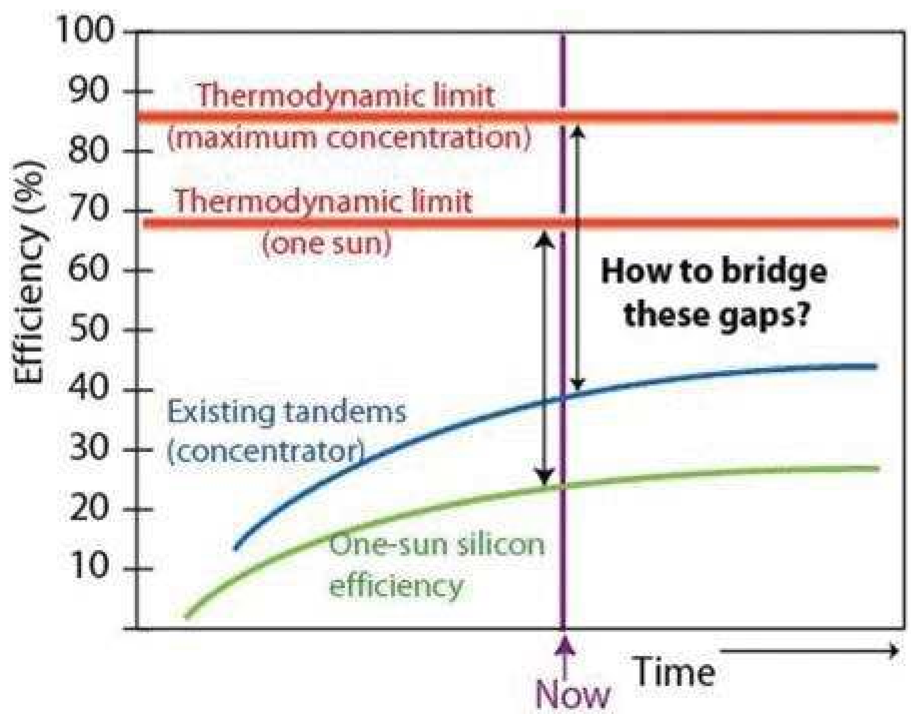

Figure 2.1: Narrowing gap between Existing and Theoretical PV efficiencies [7]

Figure 2.1 shows theorical for a solar intersection sun powered unit without daylight (one sun) is something like 31% made by the Schokley-Quiesser constrain. Under the most measure of daylight example. 50,000 suns a solitary intersection sun powered unit can have a greatest productivity of something like 41%. This productivity might be increased by using multi-intersection sun based cells by catching a greater amount of the sunlight based range.

Table 2.1: Data showing potential magnitude of future improvements in performance across device configurations [7]

Approximate Theoretical Limit Efficiency		Approximate Best Experimental Performance to Date	
Thermodynamic (concentrator)	87%	n/a	
Thermodynamic (1 sun)	68%	n/a	
Six-junction	58%	n/a	
Hot carrier	54%	n/a	
Triple-junction concentrator	64%	44%	III-V alloys, monolithic stack
Triple-junction (1 sun)	49%	15%	Thin-film amorphous silicon alloys
Double-junction concentrator	56%	30%	III-V alloys, monolithic stack
Double-junction (1 sun)	43%	12%	Thin-film amorphous silicon alloys
Shockley-Queisser single-junction (46,200 suns)	41%	30%	Crystalline silicon (500 suns)
Shockley-Queisser single-junction (1 sun)	31%	24% 20% 12% 6%	Crystalline silicon Thin multicrystalline silicon Dye-sensitized cell Organic cell

Table 2.1 shows data showing potential magnitude of future improvements in performance across device configurations , the best performance for PV thermodynamic concentrator by approximate theoretical limit efficiency 87%, the alternate configuration maybe the choice of triple-junction by approximate theoretical limit efficiency 64%. This configuration are specify by PV panel manufacture, solar panel best choose by it efficiency percentage.

2.1.1.2 Photovoltaic Working Principle

The point when light shines on a pn diode it created electron-opening combines over the entire device. Assuming that the apparatus is open circuited, the electron hole pairs generated near the depletion region tend to recombine with the charge in the depletion region, thus reducing the depletion region charge and eventually reducing the depletion region. The reduction in depletion region is equivalent of applying a forward bias to the device, this reduction in depletion region tends to develop a potential across the open terminals of the device. The maximum voltage that can be developed is the maximum forward drop across the device which theoretically is possible with the complete elimination of the depletion region. This maximum voltage that can be developed across the open circuited device is called the open circuit voltage represented by the point C in Figure 2.2. If the device is short circuited, the generated holes and electrons produce a current corresponding to the incoming photons. This current is called the short circuit current represented by the point A in Figure 2.2. When the pn device is used to drive an external load say ‘R’ the region of operation is somewhere in between these two points. The reason being a current, I flow through the device which creates a drop across the resistor and the direction of the current is such that the device comes into forward bias condition. As there is some drop across the load and the device the maximum output voltage is not equal to open circuit voltage. The forward bias conducts the device in the direction opposite to the current generated by the photons called the dark current. The presence of the dark current does not allow the device to operate at short circuit current. Thus the device operates in the fourth quadrant where the voltage is positive but the current is negative making the power negative, the device generates power using light as source.

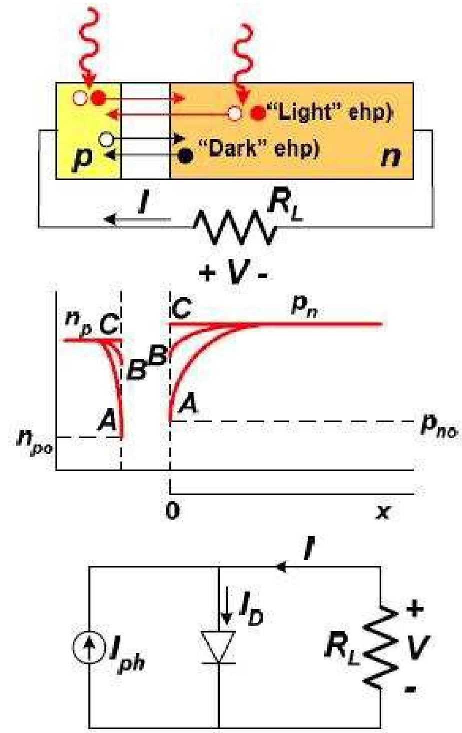

Figure 2.2 Working of a pn diode solar cell [7]

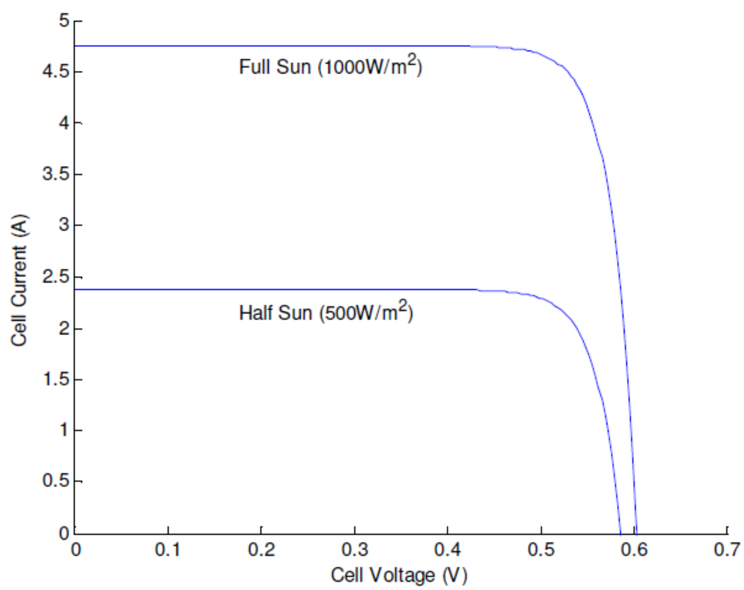

Figure 2.3: I-V plot of ideal PV cell under two different levels of irradiance [7]

The figure 2.3 show the current produce in two different weather condition, when the PV get full irradiance the cell current produce higher, this is limitation of PV depend on light intensity.

2.1.2 Supercapacitor

Supercapacitors also known ultracapacitor can be defined as energy storage device that stores energy electrostatically by polarizing an electrolytic solution. Unlike batteries no chemical reaction takes place when energy is being stored or discharged and so supercapacitor can go through hundreds of thousands of charging cycles with no degradation.

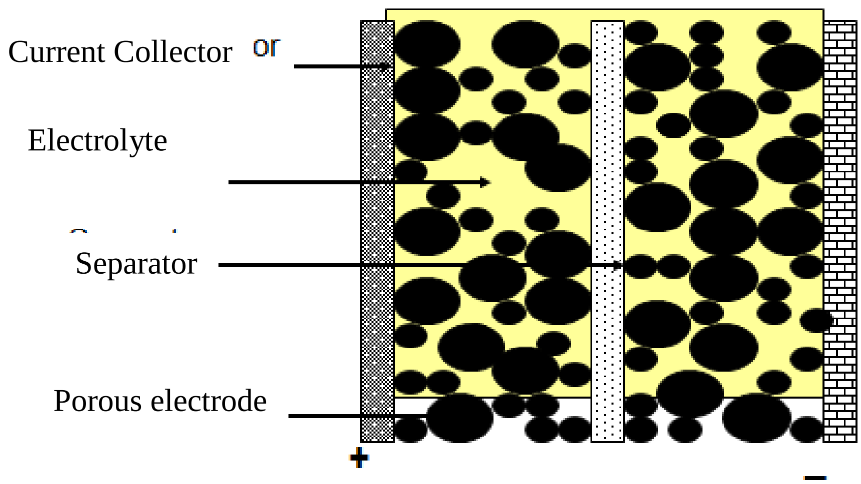

Figure 2.4: Supercapacitor electrode and electrolyte [2]

Figure 2,4 shows there are two carbon sheet separated by separator. The geometrical size of carbon sheet is taken in such a way that they have a very high surface area. The highly porous carbon can store more energy than any other electrolytic capacitor. When the voltage is applied to positive plate, it attracts negative ions from electrolyte. When the voltage is applied to negative plate, it attracts positive ions from electrolyte. Therefore, there is a formation of a layer of ions on the both side of plate. This is called 'Double layer' formation. For this reason, the ultracapacitor can also be called Double layer capacitor.