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FINAL REPORT

DEVELOPMENT OF SELF-POWERED DUAL-AXIS SOLAR TRACKING SYSTEM

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Bachelor of Mechatronic Engineering with Honours

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DEVELOPMENT OF SELF-POWERED DUAL-AXIS SOLAR TRACKING SYSTEM

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronic Engineering with Honours

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2013

“ I hereby declare that I have read through this report entitle “ Development of Self-powered Dual-axis Solar Tracking System ” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering with Honours ”

Signature : .....

Supervisor’s Name : Zamani Md Sami

Date : .....

To my beloved father and mother

I declare that this report entitle " Development of Self-powered Dual-axis Solar Tracking System " is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : CHAN ZHI HAO

Date : .....

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In completing this project, I have received a lot of helps from my supervisors, lecturers, researchers and family members and fellow friends.

First, I want to give my upmost thanks to my supervisor, En Zamani Md Sani who gave me an opportunity to do this project, for guiding and assisting me through the completion of this project. Without his guidance and persistent help, this project would not have been successful.

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ABSTRACT

Solar energy is the most readily available energy available on earth. The energy of the sun is used since ancient times. With fast growing environmental concerns over the climate change risks associated with power generation with non-renewable energy, solar power has been the best answer over the decades. However, the output power of the solar cell panel is highly affected by the sunlight incident angle. By tracking the solar panel to the sun, it can always be pointing at the optimum angle to harvest the maximum solar energy throughout a day or a year. In this project, a new method of solar tracking is presented. The sun movements are studied to design the prototype of sensor and the solar tracker. By using arrangement of six (6) Photodiode and one (1) solid cylinder, a prototype sun-pointing sensor is designed. The sensor works by determining the location of solid cylinder's shade and tracker would track the sun position in opposite direction. The dual-axis mechanism of the tracker would enable the system to track based on the sun azimuth and altitude. Two DC motors with worm gear are used as actuators; first motor rotates at x-axis (elevation) while second motor rotates at z-axis (azimuth). Also, a potentiometer is also used to read the solar panel elevation position. The solar energy harvested is then stored in a Lithium Polymer (Li-Po) battery. The method is discussed here for an automatic operation of the system which includes an intelligent tracking method, self-sufficient power supply; using microcontroller and active tracker. Moreover the prototype is designed to suit smaller system which is suitable for small domestic or household home-grown solar power plant; where it is affordable, automatous, required minimum maintenance and endplay. After the system is built, various experiments are done to test the functionality and sustainability of the tracker. The performance of the active solar tracker is also compared to the fixed solar panel to determine the improvement in solar energy harvesting capability. The tracker is able to follow the movement of sun throughout the day; while power is stored in the battery. There is also increase in efficiency of 28% when compared to fixed panel.

ABSTRAK

Tenaga suria merupakan tenaga yang paling sedia ada di bumi kita. Tenaga matahari digunakan sejak zaman purba. Dengan perkembangan yang pesat, alam sekitar menghadapi risiko termasuk perubahan iklim. Penjanaan kuasa boleh diperbaharui menjadi isu hangat. Tenaga solar telah menjadi jawapan yang terbaik bagi kuasa boleh diperbaharui sejak beberapa dekad dahulu. Walau bagaimanapun, kuasa keluaran sel papan solar adalah dipengaruhi oleh sudut tuju cahaya matahari. Dengan menjejaki papan solar terhadap matahari, ia akan sentiasa menunjuk pada sudut yang optimum untuk memperoleh tenaga solar yang maksimum sepanjang hari atau setahun. Dalam projek ini, satu kaedah baru alat pengesanan solar telah dibentangkan. Pergerakan matahari dikaji sebelum mereka-bentuk prototaip alat pengesanan dan papan solar bergerak tersebut. Dengan menggunakan susunan enam (6) fotodiod dan satu (1) silinder, prototaip alat pengesan menunjuk matahari direka. Alat pengesan tersebut berfungsi dengan menentukan lokasi bayang-bayang silinder supaya dapat mengesan kedudukan matahari dalam arah bertentangan. Mekanisme dwi-paksi penggerak itu akan membolehkan sistem untuk bergerak berdasarkan elevation dan azimuth matahari. Dua DC motor dengan wrom gear digunakan sebagai penggerak; motor pertama berputar pada paksi-x (elevation) manakala kedua motor berputar pada paksi-z (azimut). Selain itu, potensiometer juga digunakan untuk membaca kedudukan elevation papan solar. Tenaga solar yang diperoleh kemudian disimpan di dalam bateri Lithium Polymer (Li-Po). Kaedah projek ini dibincangkan di sini adalah operasi automatik yang merangkumi kaedah pengesanan, bekalan kuasa sendiri, pengawal pintar, mikropengawal dan penggerak aktif. Selain itu prototaip itu direka untuk disesuaikan dengan sistem yang lebih kecil yang sesuai untuk rumah dan loji jana kuasa kecil untuk isi rumah; di mana ia adalah berharga berpatutan, automatik, dan memerlukan kadar penyelenggaraan yang minimum. Selepas sistem ini dibina, pelbagai eksperimen dilakukan untuk menguji fungsi dan kemapanan projek ini. Prestasi penggerak solar aktif juga dibandingkan kepada papan solar tidak bergerak untuk menentukan peningkatan dalam keupayaan memperoleh tenaga solar. Kesimpulannya, papan solar bergerak itu dapat mengikuti pergerakan matahari sepanjang hari, sedangkan kuasanya disimpan di dalam bateri. Peningkatan dalam kecekapan sebanyak 29% juga dapat dilihat jika dibandingkan dengan papan solar tidak bergerak.

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LIST OF ABBREVIATIONS

Si – Silicon

RMSD – Root-mean-square deviation

NASA – National Aeronautics and Space Administration

LDR – Light Dependent Resistor

PLC – Programmable Logic Controller

PV – Photovoltaic

DC – Direct Current

A2D – Analogue to Digital

PWM – Pulse Width Modulation

Li-Po – Lithium Polymer

LP – Low Power

XT – X-tal

HS – High Speed

WDT – Watch Dog Timer

LED – Light Emitting Diode

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This chapter presents the significant of study, motivation, problem statement, project objective and scope of the project.

Since ancient time, solar energy has been used and harvested for the benefits of well-being of humans; by using the radiant light and heat of solar energy, human used the sun to dry things and to cook foods. Nowadays, the way human harvest the energy source from the sun has greatly improved. Various solar energy technologies such as heating directly from the sun, photovoltaic solar cells, solar architecture, thermal electricity, artificial photosynthesis and others can make contribution to improve humans‟ energy security.

As human awareness towards greener environment increases, human also shift from using non-renewable source of energy or fossil fuels towards renewable energy such as solar, wind and hydro energy. The clean, inexhaustible and affordable solar power is definitely the way to go for long term benefits.

1.1 Significance of Study

This study will be a significant endeavour in improving the efficiency of solar panel for electricity generation. It also includes the study of solar altitude of the sun and the mechanism for tracking system of the solar panel holder. By tracking the sun position and moving the solar panel to the direction of the sun, the solar panel holder is assured to be able to harvest the maximum solar energy throughout the day. This research will also provide recommendations on how to improve the tracking sensor for higher precision tracking. Moreover, the tracking system is to be kept at an affordable price so that individuals and household can use this method. Besides, people in underprivileged countries could benefit from the use of a solar electricity generation system. Consequently, this approach would greatly cut the electricity bill, provide basic needs for the underprivileged, decrease carbon footprint of each individuals and delay global warming crisis.

1.2 Motivation

With petrol piece increasing exponentially which lead to increases of electric bills, at no other time in our history have renewable sources of energy been more critical - for our economy, for our self-preservation, for our planet. Alternative source of energy is needed to cut down our daily expenses and to save our earth. One of the alternative renewable energy that is widely used is the solar power.

1.75×10^{17} Joules is the number of energy earth receives from the sun for each seconds. Studies show that by covering 1% of the land on earth with photovoltaic cells, human can obtain enough electricity to satiate the world‟s energy consumption until year 2050.

Solar energy can be obtained all over the globe and require little space, hence suitable for private residential power plant. Also, Malaysia is located at the earth equator which is blessed with good amount of sun light throughout the year. Malaysia receives average of 11 hours of day light every day, which makes this place very suitable for solar energy harvesting. Furthermore, as shown in Figure 1.1, the solar energy distributed

around the earth shows that there are many countries that are suitable to choose solar energy as the source of electricity.

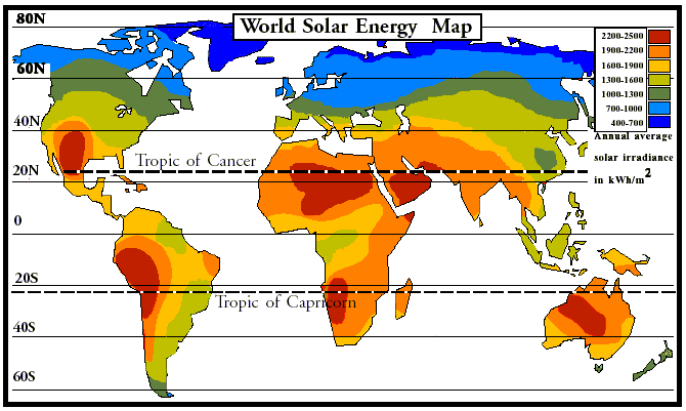

Figure 1.1: The World Solar Energy Map, shows solar distribution throughout a year [1].

The reason solar energy is preferred because it does not pollute the air when being converted into electricity. Solar energy systems would significantly contribute to reduction in greenhouse gas emissions and therefore reduce the impact of global warming and provide a better environment for future generations.

1.3 Problem Statement

One of the biggest issues with traditional fixed static solar panels is reflection. Traditional static solar panel is unable to harvest the maximum solar energy of the sun because of different position in azimuth and elevation of the sun. Referring to Figure 1.2, a lot of sunlight is either reflected or diffused away when the panel is in shallow angle. The problem worsens when there are clouds or hazes that reduce the intensity of light. This cause fixed solar panel to only harvest the maximum energy at a specific time of a day or a year, as the position of the sun in the sky moves during the day (and during the year), there are often lengthy periods when static panels cannot optimally collect sunlight especially at non-tropical countries. Efficiency of the solar panel would be optimal when the light hits the panel at a steep 90 degree. Solar tracking is one of the most straightforward methods to improve the performance and economics of a solar installation. An active 2-axis solar tracking panel holder and a sensor for tracking the sun position has to be designed to effectively increase the efficiency of harvesting the solar energy. The solar panel holders should operate with the goal of minimizing the angle of incidence between the ray of incoming sunlight and the solar panel.

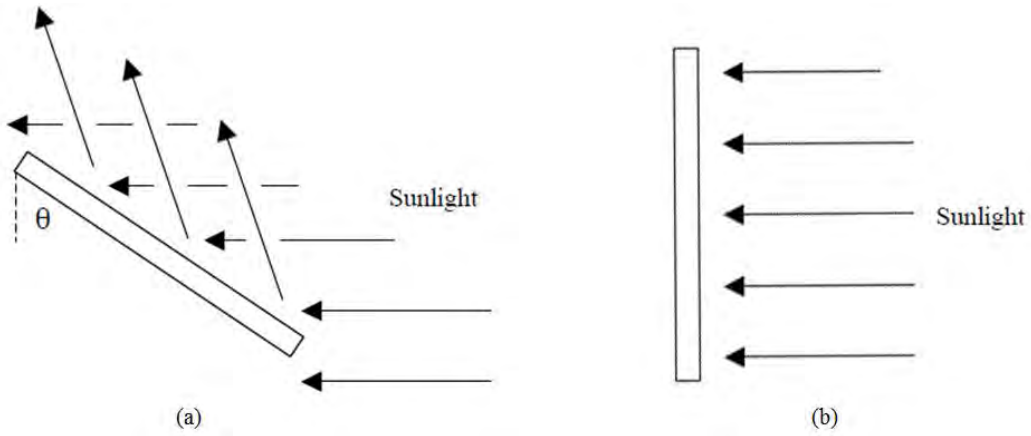

Figure 1.2: (a) The sunlight is diffused away from the panel because of the angle between the panel and direction of lights. (b) The sun light stays more focus to the solar panel as there is no angle difference.

1.4 Objective

The objectives of this project are:

1. To study the azimuth, elevation and altitude of the sun.
2. To develop a prototype tracking sensor, sending signal to the solar panel holder
3. To develop a mechanism for the actuator of the panel with 2 degree of freedom.
4. To compare the efficiency of the solar tracking panel to the static fixed panel.

1.5 Scope

The scope of this project is:

1. Development of a new type of sensory system that is able to track the sun correctly.
2. Development of a prototype solar panel holder with two-axis actuator mechanism at elevation and azimuth.
3. The solar tracker should enable the solar panel to improve harvest yield of solar energy.
4. The system should be self-sufficient by charging a battery and supply to load at the same time.

CHAPTER 2

LITERATURE REVIEW AND PROJECT BACKGROUND

To complete this project, many sources have been reviewed, which include journals, articles, books and internet. These sources served as the ideas and thoughts that lead to the success of this project.

2.1 Solar Panel Basics

A solar panel is a connected assembly of solar cells which also known as photovoltaic (PV) cells. Solar panels can be used to generate and supply electricity in commercial and residential applications by converting sun light to electricity.

Photovoltaic cells use light energy (photons) from the sun to generate electricity. Wafer-based crystalline silicon cells or thin-film cells based on cadmium telluride or silicon are used to make these PV cells. PV cells have one or more electric field that acts to force electrons freed by light absorption to flow in a certain direction. Electrical connections are made to achieve a desired output voltage and current by connecting them in series and/or parallel. The cells must also be protected from the surrounding such as scratches and moisture [2].

Doping for common semiconductor (normally silicon for PV) involves adding atoms with different number of electrons to create unbalanced number of electrons in the base material. As in Figure 2.1, in each photovoltaic cell, a p-n junction is created in silicon by the doping process. When the cells are exposed to photons, electrons will flow from n-junction to the p-junction which allows electric current to flow.

Another interesting fact is when these PV cells are made into miniature size; it became photodiode that can be used as sensor. When large cells are made, they are arranged in series and parallel to form what is normally seen, the solar panel.

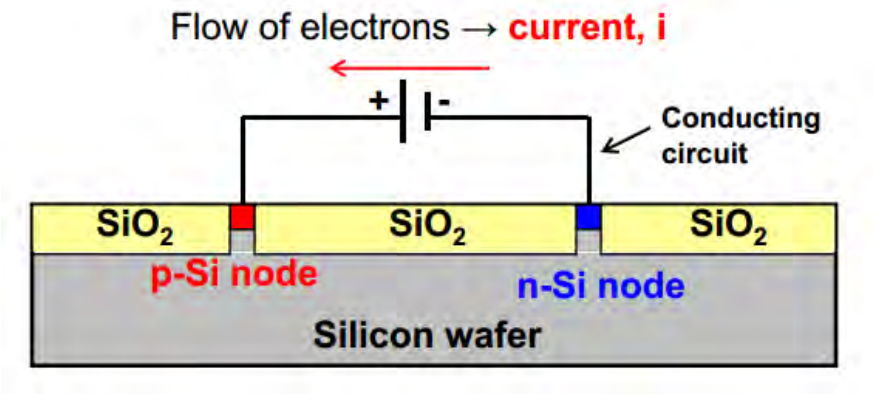

Figure 2.1: The p-SI and n-Si node in PV cells produced by doping, they cause electron to move when photons strike the surface; hence, cause current to flow [2].

Recently, some solar panel designs also include concentrators in which light is focused by lenses or mirrors onto an array of smaller cells. Also, Solar tracking also improve the solar panel to harvest the maximum light throughout a day and a year.

There are many reasons solar panels are chosen as a more preferable good alternative for electricity generation. No fuel is needed for solar energy generation; hence, does not release polluting substance. Besides, there are no or least moving parts to wear out (eg. compared to hydroelectric generation). Also, solar panels are quick responding, adaptable for on-site installation and easy maintenance. Furthermore, with the introduction of Feed in Tariff (FiT), solar power can be integrated with other renewable energy sources and the grid. Last, they are simple and efficient.

2.2 Solar Panel Angle and Some Astrology

On one day every year when the sun is positioned directly above our planet's equator, it is equinox. It is when the angle between a line that points to the sun and a line that points vertically matches the latitude of a position. In the equator, equinox happens when the sun is directly perpendicular to the equator while at the latitude of 30°, then on the equinox the sun will be 30° to the south from the vertical (see Figure 2.2). The sun's position on the equinox is the average location of the sun throughout the year and is a great reference to use when designing a solar system for a specific location.