



UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)

MOTOR CONTROLLER FOR SOLAR ENERGY OPTIMUM ACQUISITION

Thesis submitted in accordance with the partial requirements of the
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Bachelor of Manufacturing Engineering (Robotic and Automation)

By

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APPROVAL

This thesis submitted to the senate of UTeM and has been accepted as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Robotic and Automation). The members of the supervisory committee are as follow:

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DECLARATION

I hereby, declare this thesis entitled “Motor Controller For Solar Energy Optimum Acquisition ” is the results of my own research except as cited in the reference.

Signature :

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ABSTRACT

This project presents the design and implementation of a prototyped for motor controller for solar energy optimum acquisition. This prototype can be divided into two major parts: the mechanical parts and electrical parts. Mechanical parts consist of bearings, motor shaft, vertical tower, holding block and base plate. The electrical parts include the charge controller, battery, photovoltaic panel, logic comparator and other electrical components. The combination of both mechanical and electrical parts is known as Balance-of-System. There are four modules in this design, which are sensor module, logic comparator module, signal output module and battery charging module. The photo sensor in the sensor module use to detect the light source and the signal will send to logic comparator module to examine the light condition. And the signal output module analyses the signal to rotate the solar panel. Lastly, the battery-charging module will activate as soon as the light hits on the panel. Two relays used in this system with each relay control only one direction for the motor rotation besides used to regulate the flow rate of electricity from the photovoltaic module to the battery and the load. From this initiative, simple power generation via photovoltaic technology can be utilized. With environment in mind, this small step will be significant milestone for the gradual change towards renewable energy resources.

DEDICATION

For my beloved mother and father.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

AC	-	Alternating Current
AGM	-	Absorbed Glass Mat Sealed Lead Acid
A-Si	-	Amorphous Silicon
As	-	Arsenic
CdTe	-	Cadmium Telluride
CIS	-	Copper Indium Diselenide
CuInSe₂	-	Copper Indium Diselenide
CPU	-	Central Processing Unit
DC	-	Direct Current
Ga	-	Gallium
GaAs	-	Gallium Arsenide
GI	-	General Instruments
HB	-	Hybrid
I/O	-	Input / Output
LVD	-	Low Voltage Load Disconnect
kWh/m²	-	Kilo Watt hour per meter square
PM	-	Permanent Magnet
PCB	-	Printed Circuit Board
PIC	-	Peripheral Interface Controller
P_{max}	-	Maximum Output Power
PV	-	Photovoltaic Panel
US	-	United States
VR	-	Variable-Reluctance
VR	-	Voltage Regulation

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CHAPTER 1

INTRODUCTION

1.1 Background

The increasing global warming, the emission of gases that harm the environment and shortage of fossils are some of the issues, which are raised by the government and the World Wide Greenpeace. The shortage of fossils causes the oil price to increase and therefore add up the burden for the consumer. The thinning ozone layers due to harmful gases emission from the factories and the fuel burning; the dilution of glacier due to global warming will increase the sea level and floods to country like Bangladesh and India. Beside that, the fuel shortage and increasing of electricity bill bring affect to the developer and manufacturer. Both of these factors will increase the production cost and also the transportation cost. Therefore it will end up with the costly product and consumer can afford to buy it.

Realizing these crises will hinder the development and progress of a nation, there are many drastic actions and planning taken by the politician and researchers to overcome this problem. One of the solutions is seek for alternative energy for the future consumption. Among the many types of renewable energies, solar energy is considered promising as it is comparatively more evenly distributed geographically.

A branch of solar energy research that has received worldwide attention is photovoltaic. Solar technology has advanced rapidly in recent years as a direct benefit from the current development and advancement made in IC technology. Photovoltaic has shown its potential in cost reduction and better conversion efficiency. It is believed that photovoltaic system will become the primary future energy supplier.

Photovoltaic comprises the technology to convert sunlight directly into electricity. The term “photo” means light and “voltaic,” electricity. A photovoltaic cell, also known as “solar cell,” is a semiconductor device that generates electricity when light falls on it (Mah, 1998).

1.2 Problem Statement

The current problem faced in the photovoltaic system is that solar energy supplied may not always be sufficient to power the embedded system. Solar panels and energy storage elements, such as batteries have different voltage-current characteristics, which must be matched to each other as well as the energy requirements of the system to maximize harvesting efficiency. Furthermore, battery non-idealities such as self-discharge and round-trip efficiency, directly affect energy usage and storage decisions. The ability of the system to modulate its power consumption by selectively deactivating its sub-components also impacts the overall power management architecture. Beside that, most of the solar panel system is static and cannot rotate and therefore cannot obtain optimum acquisition from the sun. This is because the solar panel is fixed at one location therefore it cannot track and aligned toward the sun movement and direction. And for most the designs which is rotate-able, it is not able to get optimum energy from the sun, meaning the system just collect the sun energy without comparing which direction can collect highest data.

Therefore, based on the problems that have been highlighted, a new design is essential to overcome the problems.

1.3 Scope

The scope of the project is to make a prototype of a solar energy harvester that is capable to convert optimum solar energy from the sun using photovoltaic panel. This project will focus on the efficiency of the photovoltaic panel, which is controlled by the direct current (DC) motor. The logic comparator will remotely control this motor controller so that the photovoltaic will act as a sun tracker. A comparator will be used to compare the voltage so that when there is any changes in the voltage gain from the photovoltaic panel, the direct current motor will rotate the photovoltaic panel and align it to the direction of the sun, and stop the photovoltaic panel at the position where the comparator succeed in comparing and locating the direction with the highest value of sunlight. This process will repeat whenever this value is changing.

1.4 Objectives

The aim of this project is to design and implement a motor controller for a photovoltaic system in order to get optimum acquisition of solar energy. Throughout this project, the following objectives will be achieved:

- a) To design a photovoltaic system that is controlled by a motor controller and always aligned towards the direction of the sun.
- b) To design a photovoltaic system that is able to gain optimum solar energy acquisition.

1.5 A Brief History of Solar Energy

As we know, Malaysia is a sunshine country and it has abundant supply of solar power. Therefore we should make use of this natural energy and apply it to our daily life. There are many ways we can use to produce solar energy nowadays. The sun that is the main source for solar energy provides electricity which can be applied in our daily life. The energy gained from the sun can be used at homes, businesses, and industries. The solar energy (electricity) is produced when photons (particles of light) strike the surface of a photovoltaic panel. The electricity produced from the solar panel will be saved into a battery for further application.

Photovoltaic solar power is one of the most promising renewable energy sources in the world. This is because solar energy is environmental friendly and it does not require much maintenance. Solar energy does not cause pollution either air pollution or sound pollution. A very important characteristic of photovoltaic power generation is that it does not require a large-scale installation to operate, as different from conventional power generation stations. Power generators can be installed at anywhere using area that is already developed, and allowing individual users to generate their own power, quietly and safely (Smith, 1995).

Since hundreds of years ago, the ancient Greeks and Romans had been using the sun's capacity to light and heat indoor spaces. The Greek philosopher Socrates wrote, "In houses that look toward the south, the sun penetrates the portico in winter." With these sentences, the Romans advanced the art by covering south facing building openings with glass or mica to hold in the heat of the winter sun (Southface, 2005).

Auguste Mouchout did the inventor of the first active solar motor. Seeing the fossil fuels powering the Industrial Revolution in the 19th century, he knew that the coal will undoubtedly be used up one day and the industry will no longer find in Europe due to the fast growing and prodigious expansion of the industry. Worry that the industry will gone due to the short of fossil fuels, Mouchout developed a steam engine powered entirely by the sun in 1861. But its high costs coupled with the

falling price of English coal doomed his invention to become a footnote in energy history (Southface, 2005).

Nevertheless, solar energy continued to intrigue and attract European scientists through the 19th century. Scientists developed large cone-shaped collectors that could boil ammonia to perform work like locomotion and refrigeration. In the United States, Swedish-born John Ericsson managed to design the “parabolic trough collector,” a technology which functions more than a hundred years later on the same basic design. Ericsson is best known for having conceived the USS Monitor, the armored ship integral to the U.S. Civil War (Smith, 1995).

Albert Einstein was awarded the 1921 Nobel Prize in physics for his research on the photoelectric effect—a phenomenon central to the generation of electricity through solar cells. Due to this award, it boost backed the solar power research even though interest in a solar-powered civilization almost gone in the early 20th century. After some years, William Grylls Adams had discovered that when light was shined upon selenium, the material shed electrons, thereby creating electricity.

In 1953, Bell Laboratories scientists Gerald Pearson, Daryl Chapin and Calvin Fuller developed the first silicon solar cell that capable of generating a measurable electric current. The New York Times reported the discovery as “the beginning of a new era, leading eventually to the realization of harnessing the almost limitless energy of the sun for the uses of civilization.”

In 1956, solar photovoltaic cells were far from economically practical. The “Space Race” of the 1950s and 60s gave modest opportunity for progress in solar, as satellites and crafts used solar paneling for electricity.

The hope in the 1970s was that through massive investment in subsidies and research, solar photovoltaic costs could drop precipitously and eventually becomes competitive with fossil fuels. By the 1990s, the reality was that costs of solar energy had dropped as predicted, but costs of fossil fuels had also dropped.

However, huge photovoltaic market growth in Japan and Germany from the 1990s to the present has reenergized the solar industry. In 2002 Japan installed 25,000 solar rooftops. Such large PV orders are creating economies of scale, thus steadily lowering costs. Meanwhile, solar thermal water heating is an increasingly cost-effective means of lowering gas and electricity demand. From here we can see that technologies have changed and improved for decades. Still, the basics of solar thermal and photovoltaic have remained the same (Southface, 2005).

CHAPTER 2

LITERATURE REVIEW

2.1 Photovoltaic System

A photovoltaic panel is not able to convert the solar energy to electricity by itself. It needs to connect with other components so that it can start to collect the solar energy from the sun and then convert it to electricity for others application (Treble,1991). The basic components needed in a photovoltaic system are divided into three categories:

- a) Structure and installation
- b) Power conditioning and control system
- c) Storage batteries

For structure and installation categories, the components will include photovoltaic panel, comparator, mechanical part and all the part needed to complete the design structure. And for the power conditioning and control systems, it is more on electrical devices such as microcontroller, PCB board, wires, relay and so on. Lastly, for the storage batteries, battery is used for storing the converted solar energy gained from the photovoltaic system. This electricity will store in the battery for further application (Charles Smith,1995). The components of a balance-of-system will be discussed in depth in this chapter.

2.2 The Photovoltaic Panel

There are many types of photovoltaic panels in the market, but this photovoltaic system can be categorized into three major types; which are the stand-alone, utility-interactive system and bi-modal systems. The first operate independent of the utility grid and includes hybrid systems. The second is connected to the grid while the third has an ability to function like the first two but not simultaneously, in a book by author Jenny Nelson in year 2003, entitled “The Physics of Solar Cell”.

In other definition given by Richard D. Dorf, Editor-In-Chief of “The Engineering Handbook”, solar power system are usually classified by technology- solar thermal and photovoltaic systems principal types. Photovoltaic usually use the energy in sunlight directly to produce electricity; in solar thermal power systems, the sun heats the transfer medium such oil.

A photovoltaic system consists of solar cell electrically connected to each other in support structure to form a module. Modules are designed to supply electricity at the certain voltage, at 12 Volts. The current produced is directly dependent on how much light strikes the module. In general, larger area of a module or array will produce more electricity. Photovoltaic modules and array can be connected in both series and parallel to produce any required voltage and current. A solar photovoltaic energy conversion is a one step conversion progress which generates electrical energy from light energy. The effectiveness of a photovoltaic device depends upon the choice of light absorbing materials and the way in which they are connected to the external circuit (Dorf et al, 1996).

2.2.1 Cell Types

Two major types of photovoltaic (PV) systems are available in the marketplace today, which is flat plate and concentrators. Flat plate systems build the PV modules on a rigid and flat surface to capture sunlight while concentrator systems use lenses to concentrate sunlight on the PV cells and increase the cell power output. If we compare both systems, flat plate systems are less complicated but employ a larger number of cells while the concentrator systems use smaller areas of cells but require more sophisticated and expensive tracking systems. Concentrator systems do not work under cloudy conditions because it unable to focus diffuses sunlight. The efficiency of commercial devices is usually around 15%. (Mah, 1998)

PV cells are made of semiconductor materials. The major types of materials are crystalline and thin films, which vary from each other in terms of light absorption efficiency, energy conversion efficiency, manufacturing technology and cost of production. In this section we will discuss the characteristics, advantages and limitations of these two major types of cell materials (Garg & Prakash, 1997).

2.2.1.1 Crystalline Materials

a) Single-Crystal silicon

Single-crystal silicon cells are the most common in the photovoltaic industry. The main technique for producing single-crystal silicon is the Czochralski (CZ) method. High-purity polycrystalline is melted in a quartz crucible. A single-crystal silicon seed is dipped into this molten mass of polycrystalline. As the seed is pulled slowly from the melt, a single-crystal ingot is formed. The ingots are then sawed into thin wafers about 200-400 micrometers thick. The thin wafers are then polished, doped, coated, interconnected and assembled into modules and arrays. Single-crystal silicon has a uniform molecular structure.

Compared to non-crystalline materials, its high uniformity results in higher energy conversion efficiency where the ratio of electric power produced by the cell to the amount of available sunlight power. The conversion efficiency for single-silicon commercial modules ranges between 15-20%. Not only are they energy efficient, single-silicon modules are highly reliable for outdoor power applications (Adolf et al, 1998).

About half of the manufacturing cost comes from wafering, a time-consuming and costly batch process in which ingots are cut into thin wafers with a thickness no less than 200 micrometers thick. If the wafers are too thin, the entire wafer will break in wafering and subsequent processing (Mah, 1998).

b) Polycrystalline silicon

To reduce the cost, these cells are now often made from multi or polycrystalline silicon. As opposed to extracting a single crystal from silicon bath, these cells are formed by pouring hot, liquid silicon into molds or casts. Once cooled, and hardened, the silicon blocks are sliced in a similar fashion to the single crystal described above.

Compare to single crystalline cells, polycrystalline cells are less expensive to produce because their manufacturing process does not require many careful hours of rotating silicon material, less strict growth requirements and sawing process is not needed

The energy conversion for the polycrystalline is between 10 to 14% and is less than single crystalline cells. This is because of the grain boundaries in the structure hinder the flow of electrons and reduce the power output of cell. However polycrystalline silicon material is stronger and can be cut into one-third the thickness of single-crystal silicon material (Boyle & Godfrey, 1996).

c) Gallium Arsenide (GaAs)

This photovoltaic panel is made from a mixture of two elements: gallium (Ga) and arsenic (As). GaAs has a crystal structure similar to silicon. An advantage of GaAs is that it has high level of light absorptivity. To absorb the same amount of sunlight, GaAs requires only a layer of few micrometers thick while crystalline silicon requires a wafer of about 200-300 micrometers thick. Also, GaAs has much higher energy conversion efficiency than crystal silicon, reaching about 25 to 30%.

GaAs mostly apply in space applications due to its strong resistance radiation damage and high cell efficiency. The biggest drawback of GaAs PV cells is the high cost of the single-crystal substrate that GaAs is grown on. Therefore it is most often used in concentrator systems where only a small area of GaAs cells is needed and the prices are rather expensive (Boyle & Godfrey, 1996).

2.2.1.2 Thin Film Materials

In a thin-film PV cell, a thin semiconductor layer of PV materials is deposited on low-cost supporting layer such as glass, metal or plastic foil. Since thin-film materials have higher light absorption ability than crystalline materials, the deposited layer of PV materials is extremely thin. Thinner layers of material yield significant cost saving. Also, the deposition techniques in which PV materials are sprayed directly onto glass or metal substrate are cheaper. Therefore the manufacturing process is faster, using up less energy and mass production can be made. However, the energy conversion efficiency for a thin film PV cells are low due to non-single crystal structure. Therefore it required larger array areas and increasing area-related costs such as mountings (Zweibel & Ken, 1995).