"I hereby declare that I have read through this report entitle "Design and Implementation of a Laboratory-Scale Single Axis Sun Tracking System" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering"

Signature :…….....

Supervisor‟s Name : DR CHONG SHIN HORNG

Date : 24/06/2015

# DESIGN AND IMPLEMENTATION OF A LABORATORY-SCALE SINGLE AXIS SUN TRACKING SYSTEM

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**A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronic Engineering.**

**Faculty of Electrical Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2015**

I declare that this report entitle “Design and Implementation of a Laboratory-Scale Single Axis Sun 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 :…….....

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Date : 24/06/2015

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# ABSTRACT

Solar energy is a renewable energy which is inexhaustible and environmental friendly. The solar energy can be converted to electrical energy by using photovoltaic (PV) solar panel. Malaysia has a high potential to develop solar power plant due to the suitable location on the earth. However, Malaysia is still lack of consciousness regarding the solar photovoltaic (PV) system. Besides, power output of the solar panel is high variability and it is challenging to meet the supply-and-demand requirement. In order to have more knowledge and understanding regarding the solar system, a laboratory-scale single axis solar tracking system has been designed and developed. In order to validate the performance of the designed laboratory-scale single axis solar tracking system a series of experiment has been conducted. The designed axis solar tracking system consists of two important units which are control unit and power unit. The control unit is used to align the solar panel facing perpendicular to the sun and the power unit is used to enhance and monitor the power output from the solar panel. Data is collected using data logger in every minute from 8:00a.m to 3:30p.m. The results obtained is analyzed and discussed. The results show that the preferable angle of rotation for the designed solar tracking system is $15^{\circ}$ per hour. The designed laboratory-scale single axis solar tracking system has the performance ratio of 0.83, which is the quality factor used to determine the relationship between the actual energy output and theoretical energy output of the solar PV system. Besides, the energy saving of the designed solar tracking system can reach up to 25% in a sunny day.

# ABSTRAK

Tenga suria ialah tenaga yang boleh diperbaharui yang akan berkekalan lama dan mesra alam sekitar. Tenaga suria boleh ditukar kepada tenaga elektrik dengan menggunakan fotovoltan (PV) panel suria. Malaysia mempunyai potensi yang tinggi untuk membina dan mambangunkan loji kuasa suria kerana kedudukan yang amat sesuai di atas permukaan bumi. Bagaimanapun, Malaysia masih kekurangan kesedaran mengenai fotovoltan (PV) sistem suria. Selain itu, kuasa yang dihasilkan daripada panel suria amat tidak konsisten dan ia mencabar untuk memenuhi keperluan bekalan dan permintaan daripada pengguna. Untuk mendapat pengetahuan dan pemahaman yang lebih mendalam mengenai sistem suria, sistem pengesanan suria berpaksi tunggal yang berskala makmal akan direka dan dihasilkan. Kajian dalam projek ini diteruskan dengan mengesah prestasi sistem pengesanan suria berpaksi tunggal yang berskala makmal melalui menjalankan eksperimen. Sistem pengesanan suria berpaksi tunggal yang berskala makmal terdapat dua unit yang penting iaitu unit kawalan dan unit kuasa. Unit kawalan digunakan untuk menyelaraskan panel suria untuk menghadap berserenjang dengan kedudukan matahari dan unit kuasa digunakan untuk meningkatkan dan memantau kuasa yang dihasilkan daripada panel suria. Semua data yang diukur akan disimpan di dalam data logger dalam setiap minit dari waktu 8:00 pagi sampai 3:30 petang. Analsis akan dibuat terhadap keputusan yang diambil. Sudut putaran yang paling sesuai untuk sistem pengesanan suria berpaksi tunggal yang berskala makmal adalah 15$^{\circ}$yang berputar panel suria setiap jam. sistem pengesanan suria berpaksi tunggal yang berskala makmal mempunyai nisbah prestasi sebanyak 0.83 dan penjimatan tenaga boleh mencecah sehingga 25% dalam keadaan yang cerah.

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| FiT | - | Feed-in-Tariff |
| SEDA | - | Sustainable Energy Development Authority |
| TNB | - | Tenaga Nasional Berhad |
| MPPT | - | Maximum Power Point Tracking |
| MPP | - | Maximum Power Point |
| FKE | - | Faculty of Electrical Engineering |
| UTeM | - | Universiti Teknikal Malaysia Melaka |
| DC | - | Direct Current |
| p-si | - | Poly-crystalline solar panel |
| m-si | - | Mono-crystalline solar panel |
| a-si | - | Amorphous solar panel |
| NOCT | - | Nominal operating condition |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| $\Sigma M_o$ | - | Algebraic sum of the couple moments |
| $F$ | - | Magnitude of force |
| $d$ | - | Distance from one point to another point |
| $a$ | - | Body acceleration |
| $G$ | - | Gear ratio |
| $\tau_{output}$ | - | Output torque produced by the gear head |
| $\tau_{input}$ | - | Input torque applied to the gear head |
| $J_L$ | - | Inertia of the load |
| m | - | Mass of the body |
| $J_{L,motor\ side}$ | - | Reflection on the load inertia on the motor side |
| $R_{LDR}$ | - | Resistance of the LDR |
| $V_{supply}$ | - | Voltage supply |
| $V_{out}$ | - | Output voltage |
| $r(t)$ | - | Input signal |
| $u(t)$ | - | Control signal |
| $K_t$ | - | Motor torque constant |
| $y(t)$ | - | Output signal |
| $R_a$ | - | Terminal resistance |
| $L_a$ | - | Rotor inductance |
| $J_a$ | - | Rotor inertia |
| $D_a$ | - | Motor damping |

## LIST OF SYMBOLS (Continued)

| | | |
|---|---|---|
| $D_L$ | - | Load damping |
| $K_b$ | - | Back-EMF constant |
| $P_{difference}$ | - | Average of power difference |
| $P_{current}$ | - | Current average of the power output reading |
| $P_{previous}$ | - | Previous average of the power output reading |
| $\frac{W}{m^2}$ | - | Solar irradiance level |
| $Wh$ | - | Total energy |
| $PR$ | - | Performance ratio |
| $E_{Real}$ | - | Total energy output from the solar panel |
| $E_{Theoretic}$ | - | Total energy harvest from the sun |
| $I_{solar}$ | - | Accumulated solar radiation on each day |
| $P_{STC}$ | - | Rated power of solar panel |
| $I_{STC}$ | - | Standard irradiance condition |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

The world population is increasing throughout the year and the electricity demand is also growing rapidly. Most of the countries use fossil fuels such as crude oil to generate the electricity. The crude oil will produce much carbon dioxide, $CO_2$ and this causes global warming. The temperature on our earth is increasing throughout the year and the scientists estimate that the world temperature will raise up six degree if the greenhouse gases emissions are let uncontrollable [1].

Besides, burning the fossil fuels and forest are the factors which cause the global warming and lead to climate change. Hence, in order to decrease the greenhouse gases emission to atmosphere, governments around the world have taken some actions to support the development of renewable energy such as solar energy. Solar energy has more benefits as compared to other renewable energy due to solar energy is inexhaustible and environment friendly. The solar energy can be converted into electricity by using photovoltaic (PV) panels [2].

The governments of the countries such as China, United State of America (USA) and Australia have taken the actions to support development of solar energy. China is now the world leading manufacturer of solar cells which is the key element of solar panels.

The China government is very supportive in this solar industry. The export tax rebate for solar components has now been increased to 17%. Due to the high rebate tax provided by the government, the China‟s domestic industries are affordable to the cost to develop the solar energy. China‟s stated-owned banks are also providing the loans with the lower interest rates for the industry that involved in the solar energy program [3]. Besides, the Ministry of Science and Technology of China has launched The Science and Technology Partnership Program (STEP) in September 2012. By STEP, the China government desires to deepen its co-operation with ASEAN countries in science, technology and sustainable development [4].

Furthermore, the Australia government also shows their supports towards the renewable energy which is solar energy development. Australia government is creating renewable energy hubs which play an important role in continuing to lead on research and innovation. Besides, Australia government has launched the 2014 Renewable Energy Target Review which plans to facilitate the partnership between government, industries and research organizations [5].

Malaysia government also shows the supports to the development of renewable energy such as solar energy by developing the Sustainable Energy Development Authority (SEDA Malaysia). SEDA is a statutory body under the Ministry of Energy, Green Technology and Water. Malaysia Feed in Tariff (FiT) scheme is managed by SEDA Malaysia. The house owners who install the home solar system can sell the generated electricity to Tenaga Nasinal Berhad (TNB) through the national grid network. SEDA Malaysia FiT incentive provides a fixed rate scheme to the electricity generate and export to the grid by the households [6].

The solar tracking system is a mechanism which orients the solar panel towards the sun throughout the day from sunrise to sunset [2]. More solar energy can be harvested by using the solar tracking system as compared to the fixed type solar panel. Therefore, in this project, a laboratory-scale single axis solar tracking system is designed and developed.

## 1.2 Problem Statement

In Malaysia, solar photovoltaic (PV) system is still lack of consciousness among the nations. There are a lot of researches regarding the solar PV system around the world. However, the solar PV system is still new in Malaysia. Solar tracking system is added into the solar PV system in order to harvest more solar energy. The solar tracking system will track the sun throughout the day. The solar tracking system technology is still not well-known in Malaysia because there is lack of expertise in this field. Oversea expert is required during performing the installation and maintenance on the solar tracking system. Therefore, the laboratory-scale single axis solar tracking system is designed. It can be used as a basic or start-up tool for the researcher and educator to deepen their knowledge in the solar tracking system technology.

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## 1.3 Objectives

The objectives of this project are:

1. To develop a laboratory-scale single axis solar tracking system.
2. To examine the energy optimization of the solar tracking system by using offline method.
3. To investigate power output variability characteristics of the solar tracking system.

## 1.4 Scope

- The microcontroller Arduino Mega 2560 will be used as an integrated control unit in the designed laboratory-scale single axis solar tracking system.
- The solar PV panel which chosen to be used in this solar tracking system is SOLARLAND SLP-020-12. It is a 20W and 36 solar cells poly-crystalline (p-si) solar PV panel. The dimension of the solar panel is 450*mm* (Length) x 340*mm* (Width) x 25*mm* (Thickness).
- The Light Dependent Resistor (LDR) is used as the sensor in the solar tracking system to identify the day and night time at the surrounding.
- The DC geared motor is used to act as the actuator of the plant. The DC geared motor is installed with the gearbox which has the gear ratio of 25:1 to provide a high torque and low speed application such as solar tracking system which does not require high speed rotation system.
- The experiments are carried out in Faculty of Electrical Engineering (FKE), Universiti Teknikal Malaysia Melaka (UTeM). The laboratory-scale single axis solar tracking system is designed and the performance of the solar tracking system is validated by performs a series of experiment.
- The power outputs from the solar PV panel are monitored by using the DC power meter. The experiment time duration will be 7 hours and 30 minutes. The power output from the solar PV panel will be collected in every minute from 8:00a.m until 3:30p.m. All the measured data will be recorded in the data logger for analysis.

## 1.5 Report Outline

Chapter 1 provides the introduction regarding the solar tracking system and Chapter 2 provides the background study regarding the solar photovoltaic (PV) system. In Chapter 3, the method to design the laboratory-scale single axis solar tracking system and the derivation of DC geared motor transfer function are presented. Furthermore, the experimental setup and procedures to collect the data are described too. The experimental result is analyzed and discussed in Chapter 4. Finally, the conclusion and recommendations are presented in Chapter 5.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Project Background

Energy plays an important role in human daily lives. The energy is generated from the renewable energy and the non-renewable energy. Decade ago, before the invention of the renewable energy technology, the energy is generated using the non-renewable energy such as fossil fuels and crude oil. The non-renewable energy will produce a lot of greenhouse gases such as carbon dioxide, $CO_2$ which will cause the global warming [1]. Besides, the fossil fuels such as crude oil is nearly exhaust in our world. Due to the shortage of the crude oil available, the price of the crude oil is increasing and it causes a lot of burden to the countries which depend on the crude oil to generate electricity. Researches have put many efforts to overcome this problem. By using the renewable energy such as solar, biomass, wind, tides and waves, the electricity can be generated easily without using the non-renewable energy.

One of the most famous renewable energy is the solar energy. Solar energy has many advantages as compared to other types of renewable energy. Solar energy is produced by using the radiated sunlight provided by the sun. There are two main types of solar energy conversion of sunlight radiation to the electricity which are concentrated solar thermal plant (CSP) and photovoltaic(PV) plant [12]. This project is concerned on the PV plant which is a solar PV system. The solar energy is inexhaustible and environmental-friendly. By using the solar energy instead of crude oil to generate electricity, the quality of

environment and air on the earth can be improved. The solar energy can be converted into electricity using the photovoltaic (PV) panels [2,13].

Table 2.1 : Advantages and disadvantages of solar energy [12]

| **Advantages** | **Disadvantages** |
|---|---|
| Clean | Only available on day times |
| Noiseless | High cost of installing solar panels |
| Very little maintenance | Low efficiency in generation of electricity using solar panel |
| Last forever | Amount of electricity generated depend on the sunlight exposure condition. |
| High reliability | |
| Save environment | |

Malaysia is suitable to install the solar PV system due to the coordinate on the earth. Malaysia is at the equator of the earth which lies between $1^0N$ and $7^0N$ , and $100^0E \; and \; 119^0E$. Malaysia receives more than 10 hours sunlight daily and 6 hours direct sunlight which has the solar irradiance level between $800^{W}/_{m^2} \; and \; 1000 \; ^{W}/_{m^2}$. Malaysia has a great potential to develop the solar energy due to the long period of receiving sunlight [14-15].