UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FACULTY OF ELECTRICAL ENEGINEERING

FINAL YEAR PROJECT REPORT

DESIGN DUAL AXIS SOLAR TRACKER THAT MOVE INDEPENTLY IN X AND Y DIRECTION TO TRACK MAXIMUM ENERGY

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“ I hereby declare that I have read through this report entitle “Design Dual Axis Solar Tracker That Move Independently In X And Y Direction To Track Maximum Energy” and found that it has complied the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

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DESIGN DUAL AXIS SOLAR TRACKER THAT MOVE INDEPENTLY IN X AND Y DIRECTION TO TRACK MAXIMUM ENERGY

WEE CHUAN CHIN

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

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MAY 2018

I declare that this report "Design Dual Axis Solar Tracker That Move Independently in X and Y Direction to Track Maximum Energy" 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 the candidature of any other degree.

Signature : ……………………………………..

Name : Wee Chuan Chin

Date : 18h May 2018

ACKNOWLEDGEMENT

First of all, thanks to God because of Him I have this opportunity to have an amazing experience to successfully finishing this report. In preparing this report, I was in contact with many people, researchers, academicians and practitioners. They have contributed towards my understanding and thought. In particular, I wish to express my sincere appreciation to my project supervisor, Prof Madya Dr Kasrul Bin Abdul Karim for the continuous support of my Bachelor study and research, for his patience, motivation, encouragement, guidance critics, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I am also very thankful to my parents and friends and would like to express my gratitude for always give me moral support and pray for me in order to finish this final year project. Without their continued support and interest, this project would not have been same as presented here. Not to forget to Universiti Teknikal Malaysia Melaka (UTeM) for supplying the relevant literatures. My fellow postgraduate students should also be recognized for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members.

ABSTRACT

As we can see now, the earth becomes hot effect of the global warming. Here we can take an advantage from the effect of the global warming. We can use solar energy as an electrical energy to operate an electrical appliance. The problem that we can see now is most of the solar panel that had been use by a user just only in a static direction. If the solar panel located at east and the sun is located at west, the solar panel cannot be charging. So, the project that wants to develop here is called "Design Solar Tracking System to move independently in X and Y axis to Maximize Energy". Solar tracking system is the project that used Arduino Uno microcontroller as a brain to control the whole system. The LDR (Light Dependent Resistor) had been used to sense the intensity of light at different angle and sent the data to the microcontroller. This microcontroller will compare the data and rotate a stepper motor to the right direction. The stepper motor will rotate the solar panel based on the highest intensity of light.

ABSTRAK

Seperti yang kita ketahui sekarang, bumi menjadi semakin panas kesan daripada pemanasan bumi. Kita boleh mengambil kelebihan daripada kesan pemanasan bumi yang sedang kita hadapi sekarang. Kita boleh menggunakan matahari untuk menghasilkan tenaga elektrik bagi menggerakkan perkakas elektrik. Tetapi masalah yang dihadapi sekarang ialah solar panel hanya berada dlm keadaan satu arah sahaja(statik). Oleh itu, projek yang hendak dihasilkan di sini dipanggil "Design Solar Tracking System to move independently in X and Y axis to Maximize Energy". projek ini menggunakan mikropengawal Arduino Uno sebagai otak untuk mengawal keseluruhan projek ini. LDR (Light Dependant Resistor) digunakan sebagai pengesan untuk mengesan keamatan cahaya pada berlainan posisi dan menghantar maklumat ke mikropengawal. Mikropengawal akan membandingkan data tersebut dan menggerakkan motor stepper ke arah keamatan cahaya yang tertinggi.

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LIST OF ABBREVIATIONS

I/O	-	Input Output
RAM	-	Random Access Memory
ROM	-	Read Only Memory
PROM	-	Programmable Read Only Memory
EPROM	-	Erasable Programmable Read Only Memory
IC	-	Integrated Circuit
R	-	Resistor
LED	-	Light Emitter Diode
K	-	kilo
V	-	volt
mA	-	mili ampere
LDR	-	Light Dependant Resistor
PCB	-	Printed Circuit Board

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CHAPTER 1
INTRODUCTION

1.0 Background

Exponential growth of population and economic development has put an impact on our world which raised consumption in these few years. Our world nowadays, yearly there will be rapid growth of industrial society mainly caused by fossil fuels energy such as nuclear energy, coal energy, natural gas and etc.

Renewable energy sources such as electric power have overtaken as main role to fulfill the needs of electric energy. The extinction of fossil fuel resources are been expected to ends within the next hundred years from now onwards. Basically, renewable energy that produced naturally through environment surroundings are mainly will keep going to replenished one day. Sources that keep continuous renewed constantly are biomass, wind, sunlight, water, geothermal and heat. In terms of renewable energy, solar energy is listed as the highest energy to get the most efficient energy to produce electricity generation .It is mainly chosen as the primary energy resources in warm climate country in our world.

Solar technology is also one of the fastest growing renewable energy since its source is always continuous, cheap in price, pollution free and friendly environmental. Solar radiation is basically act as a solar energy that beam radiation to solar PV panel for a period of time that is called as solar irradiation. There are three different combinations for solar radiation which are diffused, direct and reflected radiation that will be displayed in Figure 1.1. The main problem and limitation for solar energy is when there are certain condition occurred. One of it is caused by weather which can be wet or cloudy that causes the solar PV panel to absorb less sun radiation which unable to produce electricity on its maximum.

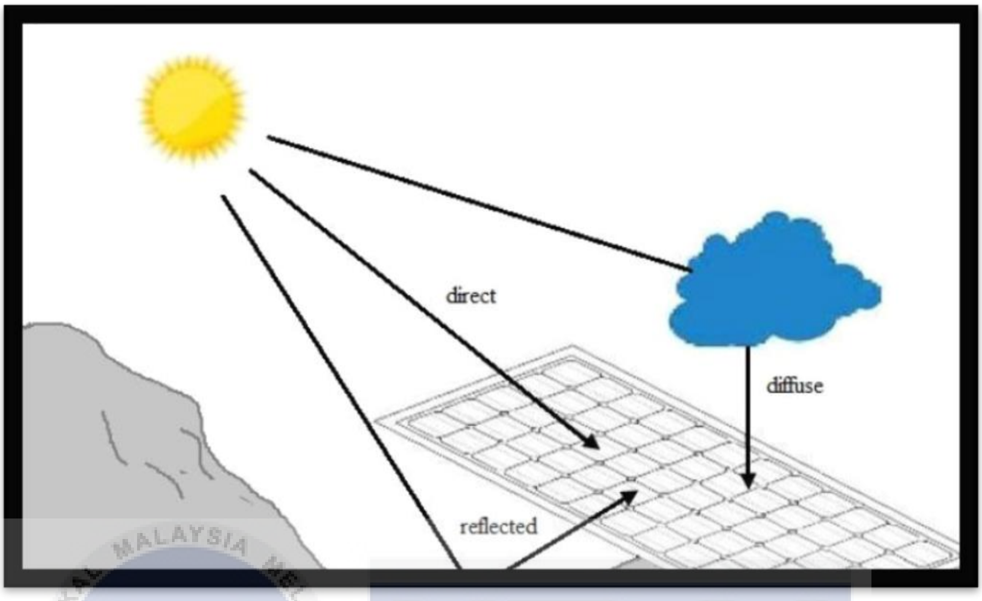


Figure 1.1 Types of solar radiation

Moreover, the problem occurred on solar photovoltaic is of its low efficiency. This is a problem to generate maximum output power absorbed by the sunlight. The solution for this, research have been made by researches that the only solution to be carried out is by increasing the efficiency output power by implement solar tracking system. It's been widely used now in our world technologies nowadays. It works as to align the solar PV panel to be perpendicular to the position of the sun radiation. There are elements that merged together to create and design this solar tracking system which are electrics, electronics, and mechanics.

Thus, by implementing the tracking system for solar PV, the solar energy efficiency can be increased and improved. This system can help to increase the efficiency output power to get the maximum result.

1.1 Problem Statement

In our world, not all countries have big resources such as oil and gas to generate and produce electricity. It is been assumed that one day, the fossil fuel will extinct when its been overused. Renewable energy is well known to this world as its continuous sources that will keep reproduced. Consumers frequently use solar energy as a renewable energy to charge small devices and portable appliances for their daily usage.

Nowadays, strength efficiency to generate solar energy power is low. However, lack of accuracy and efficiency is a major problem as well with the incensement of operation energy consumption. In order to solve this issue, solar tracking system has been recognized in our world. Generally, the solar tracker act as device that will orient and move the solar PV panel to be aligned with the sun position. It will as well reduce the angle between lines to force the solar PV panel to be perpendicular with the sun radiation. When there is a change of solar irradiance intensity, the solar PV panel will automatically change its direction.

Solar tracking system is more costly to be produced because it doesn't need a big area of perimeter to produce and generate power compared to other big generation system. There are basically two types of solar tracking system which are fixed tracking system and dynamic tracking system. Dynamic solar tracker categorized as passive and active tracker. The active tracker is much more reliability because of its capability to produce higher efficiency compared to the passive tracker that have to depend on the weather. Dynamic solar tracker much more preferred to be used

Active tracker adapted to sense the light intensity by using sensor such as light dependent resistor (LDR) .Then, the other will be the photo diode constructed to the motor to align the position of the solar PV panel. Basically, dual axis trackers will be more accurate. However, the design of dual axis tracker is much more complex in terms of its circuit as it involved electronic parts which are sensors, microcontrollers, servo motors, resistors and etc.

Therefore, the main problem that needs to be solved is to find solution to lessen the energy consumption and how to increase the efficiency power of dual solar tracker by improving its hardware system.

1.2 Objective

In order to utilize a great solar power system, a solar tracker is very important in terms of its effectiveness. Thus, this project has three main objectives as follows:

1. To design dual axis solar tracker that move independently in X and Y axis direction

2. To implement system in terms of hardware and software of the solar tracking system by aligning the solar panel in the direction of the sun throughout the day by tracking maximum energy

1.3 Scope

One of the scopes of this project is to create and design an intelligent method using solar tracking system. This system will measure the strength of light intensity by using four LDR sensors that will be placed on the top of the solar PV panel to get the best sun radiation. The tracking system will move its surface of the solar PV panel to orient and align with the incoming sunlight beam. There will be two DC servo motor used in this system as the motors will rotate in certain direction. The motors will move into their desired position movement and angles based on the signal transmitted controlled by microcontroller which is Arduino.

For this project, there are two criteria been considered which are the software and hardware part that need to be developed in this project. The major part of this project is more focusing on the hardware development which are the microcontroller Arduino, servo motor , LDR light sensors, servo motors and solar tracker mechanism that to be used on the solar tracker. The microcontroller which is Arduino function as the best microcontroller as it meets the best criteria for this project as in terms of its effictiveness.The effectivenss are based on the power consumption, the adaptation of its signal to the sensor, number of output and input , speed and etc.

The input system works when the LDR sensors operated to detect and identify the light intensity of sunlight. It is mainly based on its sensitivity, position and accuracy. The motor drivers which are the servo motors are been used in the project of its capability to direct the position and control the solar tracker to move accordingly to the sunlight. Servo motor is used because of its great torque that able to rotate the solar PV panel in a smooth rotational, low cost and less power consumption needed to operate this system. The mechanism of solar tracker is created and designed to meet the objective which is a system that able to track solar energy.

Lastly, programmers are developed in this system which are based on the microcontroller Arduino.This is to help the system to meet the desired output which are the position and direction of solar PV panel. The fuzzy coding is intended to produce the best controller to control the accuracy, precision and movement of the solar tracker system. The Arduino which is written in C++ language is bee operated and executed in this project.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

Our global world now facing with extinction of oil and fossil fuels which is a serious threat to our world.This affects the Earth resources causing deterioration of atmosphere environment and global warming. Rapid growth of population and economic crisis leads to energy saving and protection for environment in our world.

Regeneration energy also known as green energy has been enlarged bigger attention. Green energy can be recycled repetitive and can be used every time such as water, wind power, biomass, sea waves, tides and solar energy. Among this green energy, solar energy is the main dominant resource that can be used to produce power. A good energy source prospect for industrial continuous processes needs to be:

- More or less constant energy throughout the year;
- Highly reliable and needs little maintenance;
- Low cost to construct and operate;
- Virtually green environmental and landscape friendly;
- Modular flexible in size and applications;

2.1 Concept of Solar Radiation

Theoretically, solar radiation is beamed when it is produced by the sun. There are two type of solar radiation which is direct radiation and diffuse radiation. Direct radiation occurs when the solar hit directly to the solar PV panel .By means, around 90% of the solar been carried by diffuses energy radiation .In other word, diffuse radiation is when the solar been scattered caused by weather , wet environment , cloudy and etc. It is mainly caused when the solar energy flash towards a cloud before had been beamed into solar PV panel. The energy radiation is the main incident radiation that has been replicated by our earth. This radiation is called as global radiation on a solar PV panel [1].

2.1.1 Introduction of a Solar Tracking System

Generally, solar tracking system is a appliance device that used for positioning a photovoltaic panel pointing the sun to minimalize the angle incident in between of sun and surface of solar panel throughout the day. It has the best performance when it is pointed straight to the sun as the value of efficiency of the output power is the maximum. Thus, it wills causes complexity and add cost to this project which is a negative side to the project.

The amount of intensity of solar radiation is decreased when the system rotates mechanically towards to face the sun and getting the highest intensity of solar radiation. One of the benefits is that it can help to maximize the effectiveness of the power from the solar energy. Then, the disadvantage will be the operation energy consumption will be high when the system is operated which causing the system to be hard to yield more output than expected. [2].

Fundamentally, a well-organized solar tracking have to function at its maximum to generate maximum output power with low energy consumption at the same time. Mostly of the PV installation located in Malaysia are basely individual systems. The grid connected PV taking place with some test installation recently. In

2002, Prototype Solar House been constructed in Kuala Lumpur as a part of Research and development of Grant Scheme (IGS) [3].

It is magnificent meanwhile in a normal residential area, house dissimilar of grid-connected roof installation with not the same photovoltaic generators (polycrystalline, monocrystalline, amorphous silicon; mounting, integration and roof tiles) have been constructed with highlighting on architecture and thermal features. [4].By allowing the evaluation of relevant operation parameters for PV systems, the installation is much more dependable and reliable with greater efficiency. There are as well certain aspects that been used related with grid connected system of PV in Malaysia.

2.1.2 Types of Solar Tracker

In order to get the maximum efficiency of output power, position of solar PV and sun must be both perpendicular in alignment .Nowadays, there are many different types of tracking system that can be used which are different in terms of its rate, accuracy, reliability and etc. The design of the solar tracker must be selected accordingly to make sure the tracking system can be constructed with great results at the end by getting high output power.

2.1.3.1 Single Axis Tracker

This tracker consists of one degree of freedom. It operates as an axis as the movement of single axis can be either on 2 directions which are horizontal and vertical axis. The movement of this system is variable upon the technology adapted on the tracker as well the prototype mounted on it. Each country in tropical region such as Malaysia is set up as horizontal type tracker as the sun usually has the lowest point of getting the high solar intensity.

A single axis tracker normally moves in a place. It will alternatively move and rotate in either two positions which are horizontally and vertically. It is less difficult to control this tracker and the price of built this is quite low and affordable. [5].The problem is the efficiency of getting much solar irradiance is not enough and low for the solar tracker system. Figure 2.1 and Figure 2.2 displays the types of solar single axis tracker.

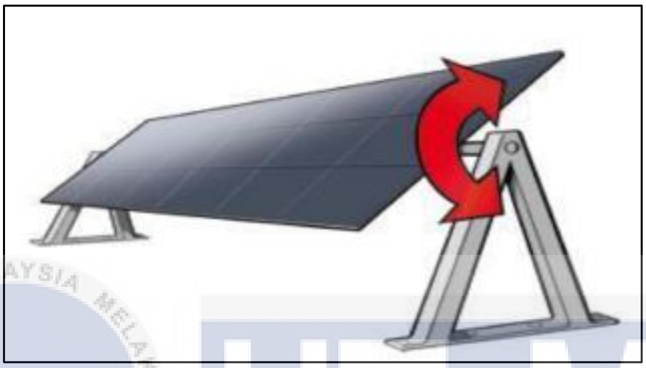


Figure 2.1 Horizontal Single Axis Solar Tracking System

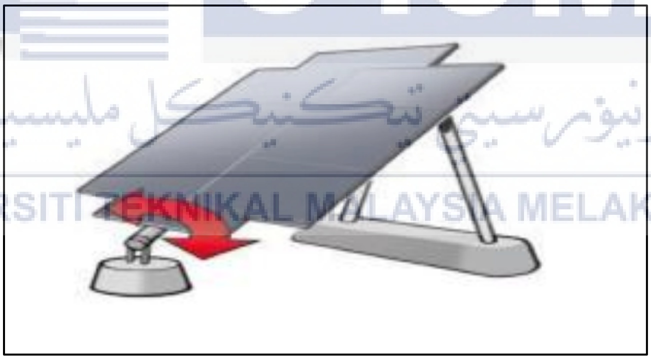


Figure 2.2 Vertical Single Axis Solar Tracking System

2.1.3.2 Dual Axis Tracker

By using DOF, a dual axis tracker will rotate freely which can be horizontal and vertical axes. It will rotate in a form of vertical axis which is from east to wear or west to east. The horizontal axis will then move from north to south or south to north .The movement will depends on its location of the sun .Dual axis will give much more greater performance and accuracy compared to single axis tracker. The sun position will be flashed to solar PV panel which the controller of the signal will be controlled by a microcontroller.

The sensors are placed on the top of PV panel will help to get as much as rate of current and voltage to be absorbed by the sun. [22].A dual axis tracker normally will increase the output power by 40-50% compared to single axis tracker which will be much lower [6].. Figure 2.3 displays the example of tracker which has two degree of freedom.

Figure 2.3 Dual Axis Solar Tracker

2.2 An Overview of Solar PV panel

A solar PV panel is a solar module or as known as photovoltaic panel (PV). Photovoltaic cells are assembled by a PV panel. PV solar panels help to absorb great amount of total surface of solar energy .A greater photovoltaic system can help to generate higher supply of electric for commercial purpose and residential area. The output power can be ranged in between of minimum range of 0 to 100 watts and for the maximum range between 0 to 320 watts. [7].

The effectiveness of the solar PV panel will help to identify the total region places of area If many solar panel are been used in an array, there will e more power that can be harvested.. [24].

2.3 Type of Solar PV Panel

Generally, the are many types of solar PV panel which will be listed as:

i. Poly-crystalline (p-Si)

ii. Mono-crystalline (m-Si)

iii. Amorphous Silicon (a-Si)

iv. Ribbon Silicon

v. Chalcogenide films of Cu (CIS)

The parameters on a solar cell will keep changing if the light intensity changes as well. This is due to exposure of open circuit voltage, efficiency, effect of series resistances and short circuit current. [8]. Therefore, changes of ups and downs effects the total power of output from the solar panel.

2.4 Efficiency of solar panels

The effectiveness efficiency is basically depends on the performance of a solar cell to another cell panel. The ratio of energy output to input energy from the sun always varies from time to time. The intensity of the sunlight and temperature will be different as during the day there will be different humidity and weather. The conditions forced to be measured as it must be controlled precisely when the performances of devices various every time.

2.5 Working of Photovoltaic

The direct conversion of light that converts into electricity at atomic level is called as Photovoltaic. Normally, there will be some materials that will display a property which is called as photoelectric effect. It will root to captivate photons of light then will discharge the electrons. [9].The electric current will be used as electricity when the free electrons are apprehended. A solar cell will be in solid state when the electrical device varies the energy of the light. The common and most used today is crystalline silicon PV cells. [20].

Photovoltaic module is when a big number of solar cells electrically merged together to each other. It is then been mounted to support the frame and structure of the module. Normally, the modules that designed to support certain voltage which are commonly used 12 volts system. [19].The current formed is unswervingly dependent on the amount of the light strikes the module shown in Figure 2.4.

Numerous modules can be wired together to form an array. Generally, the bigger the area of a module or array, the greater the amount of electricity will be produced. Photovoltaic modules and arrays harvest direct-current (DC) electricity. [12].They can be connected in both series and parallel electrical arrangements to create and produce any required voltage and current combination.

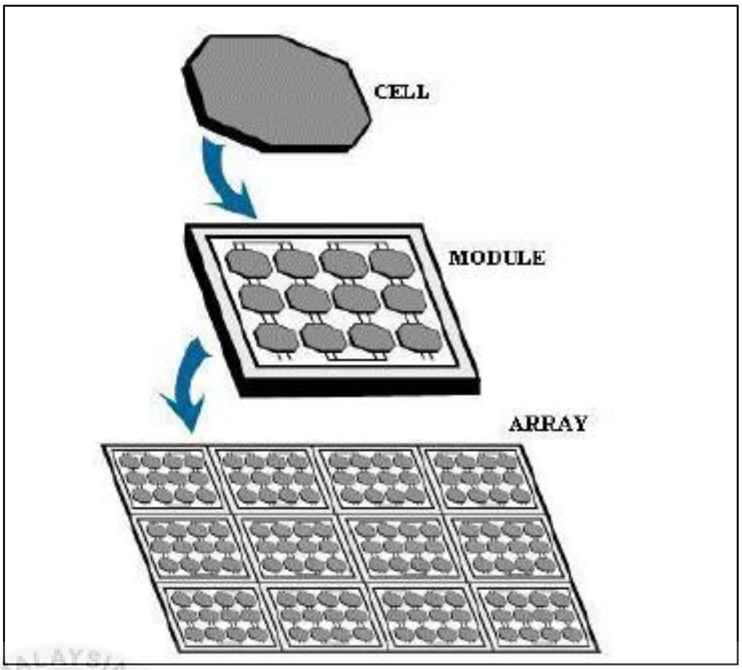


Figure 2.4 [13].

2.6 Application of Solar Energy

The usage of solar radiation practically will never ends since its primarily uses solar energy. Those that originate their energy from the sun is those renewable energy that are others than geothermal and tidal. [24].

Solar technology is largely categorized that can either two which are active and passive. It depends on the way it been captured, converted and allocated towards the sunlight. For passive solar, there are many properties been used such as thermal, circulation of position towards the sun, designing the space and etc. In other than, for active solar, techniques used are photovoltaic panels, fans and pumps that will directly convert sunlight into productivities material that can be useful in future. [18].Active solar help to increase the amount of supply energy but for passive solar, it will lessen the needs of resources which generally considered as demand side of technologies.

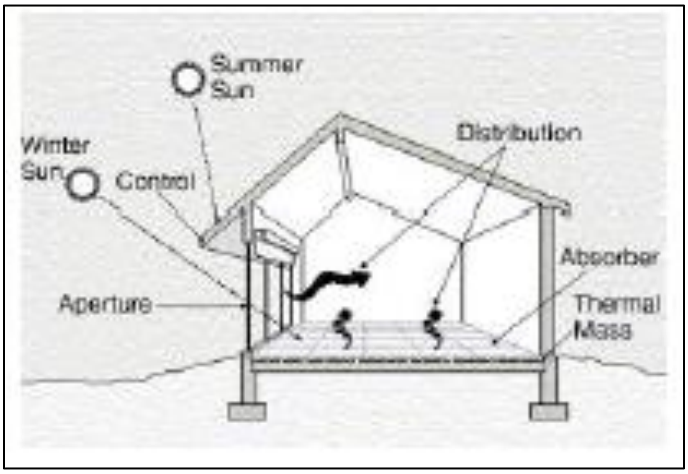


Figure 2.5 Construction and urban planning

Figure 2.6 Agriculture and agriculture

Figure 2.7 Heating, cooling and ventilation

2.7 Previous Project

After I have studied well about the past project which is also known as Solar Tracking System.I came to realized there are some disadvantages. The main one is that the previous one used two sensors to detect the light intensity while the current I am doing now using 4 sensors which is much more efficient. The rotation of solar panel is much more precise for the current project as it move freely compared to previous one that moved in one degree of freedom which is a limited movement. Table shows the detail about the comparison between previous and current project.

Description	Current Project	Past Project
Microcontroller	Arduino Uno	Intel 8051
Number of Sensor	4 sensors	2 sensors
Direction Sensor	0-360 degree total	45 degree total
Type of Circuit	Simple	Complex

Table 2.7: Comparison of previous and current project

CHAPTER 3
METHODOLOGY

3.1 Overview

In this research, tracking system divided into two which are active tracking and passive tracker. For the first active tracking, it uses gears such as motors to relocate the solar tracker to move its correct angles towards the sunlight. Trackers will then help the sensor to detect the sun to get the signal and transmit the data into the controller. There is as well tracker that constructed as in solar map which it is liable towards its location. It gives information where the sun will be at during the day throughout the year. It doesn’t need sensors input to keep tracking the sun but there are also tracker that uses combination both of sensors and solar map. The sensors will track the sun during sunny weather but during cloudy weather, the information of the solar map can be used. It is much more significant to keep tracking the sun even though the weather is a problem for solar panel to generate energy during that condition.

Moreover, the passive tracker functioning as it uses compressed gas to change the movement of tracker. When there are differences in gas pressure that been created, the tracker will move itself to reach its equilibrium position. The benefits of the passive tracker are that the system does not use a controller but the bad side is that this tracker is vulnerable to wind changes and the response is slow.

3.2 Materials

3.2.1 Sensors

Devices that are subtle and sensitive towards the light can be implemented in designing solar tracking system. The devices can be placed and located as an angle as displays in the figure 3.1.

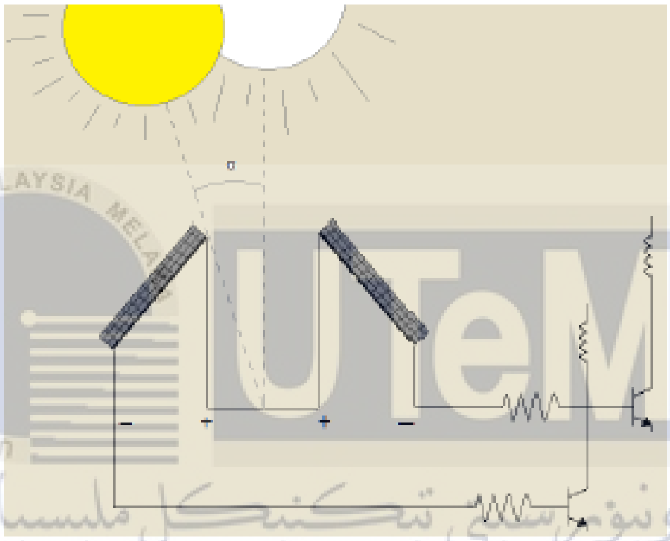


Figure 3.1: Sensors

The sensors on the left side will receive more light compared to those to the right when the sun is positioned on the left position. The left sensor would produce higher amount of voltage when the light intensity on the left side is higher. Results, we can know that the location of the sun is positioned towards on the left side. We as well can know that the sun must be at vertically perpendicular top position when the two sensors getting the same output value.

3.2.2 Photovoltaic cells

Combination of solar panel is called as Photovoltaic cells. It can be used to detect and sense the light solar intensity. It will generate maximum voltage when the sun is vertically on top of the solar cells. When the angle incident decreases, the voltage will as well decrease. The voltage will produce minimum output when the cells are in parallel with the sunlight direction.

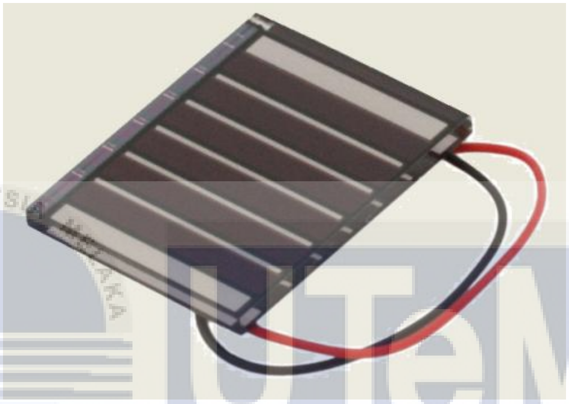


Figure 3.2 Photovoltaic cells

3.2.3 Light Dependent Resistor (LDR)

Light dependent resistors or photoresistor is a type of resistor who resistance be determined by the amount of light falling on the sensor. To attain these appreciable variations of radiation, a block of sensors with four photodiodes was designed in a way that will aid of a structure in form of a cross the stages of radiation are more sensitive to the variations of the position of the sun to its own shade. Additionally, this block of photodiodes is positioned on the same plan as the photovoltaic panel as displayed in figure (3.2) .The resistor of LDR increases with decreasing light intensity.

Then, the four LDR sensor will be connected and placed on top of the designed solar PV panel .Each side of LDR will be connected to the Arduino and fixed with each analog pins.The sensors will be placed conferring to different pole side which are north, south, east and west of solar panel. Figure 3.3 shows the block scheme which four different pole side. The sensors then will detect the light intensity of sunlight. It then will compare the intensity strength by using resistance of 10k ohm which acts as proportional controller.

The LDR changes its resistive value which depends on the light intensity and its output voltage. The difference in voltage will be as each junction for different strength of light intensity. The LDR resistance vary with different light intensity been flashed out on the cross configuration in Figure 3.5.

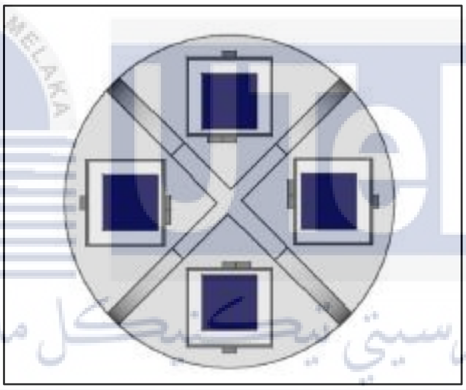


Figure 3.3: Sensors block scheme

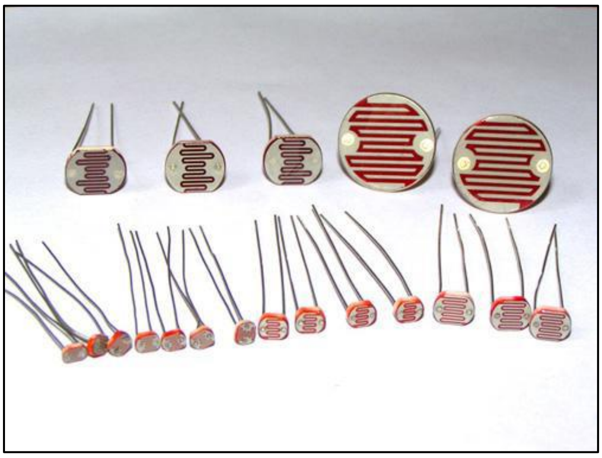


Figure 3.4 LDR Sensor

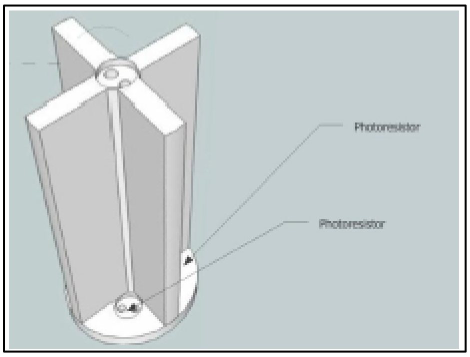


Figure 3.5: Cross Configuration of Photoresistor Frame

The design allows each of the four photo resistors to be rectilinear in reverse directions such as shows in Figure 3.5.The angle permits to accurate detection of the location of the light source. The cross design allows for a sun-dial effect for the four photoresistors. The photoresistor within the direction of the light source obtains the greatest quantity amount of light while the others are shaded out.

In cooperation designs, the panel will change toward the direction of the photoresistor with the lowermost resistance (facing the greatest light intensity) and will carry on moving until resistance in each photoresistor is around the same. Equivalent resistance levels point out that the solar panel is directly oriented in the position of the light source.

3.2.4 Light Sensor Design

The solar tracker system fully uses a photocell in sensing light intensity. By using 10k ohm, we can balance the resistor value. The output voltage will increase when the light intensity increase as well. As a result of configuration, the value of resistor is selected based on the greatest output range that can be achieved in this project

The value of the resistor is chosen as widest output range has been achieved. The conditions are been measured based on its light condition which are dark, average, and bright condition.

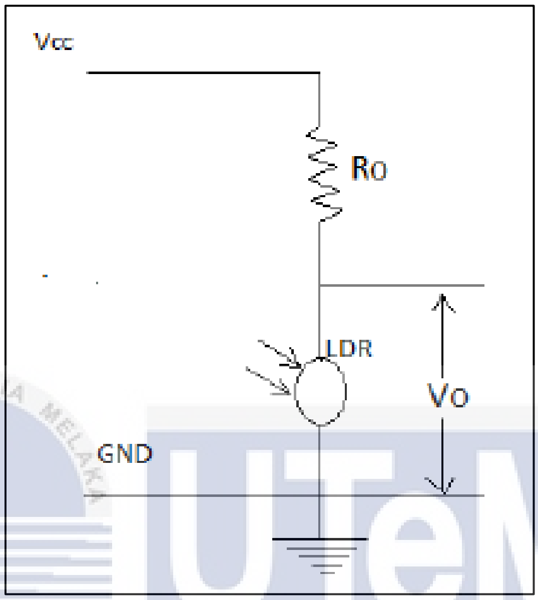


Figure 3.6: The input circuit that employs a voltage divider.

Table 3.6 shows the relationship between the input outputs for the voltage divider circuit. The voltage divider to get and find the voltage difference when it is bee attached with the LDR that will have various resistance value. [28].

3.2.5 Arduino UNO R3

The microcontroller used for this project is Arduino UNO R3. This board contains of 14 different bi directional input and output pins. There are 6 pins which supports PWM output. 6 analog input pins and a reset button. This microcontroller I the best at its operation that been structured with power jack supply and also with a connection USB cable. Figure 3.8 and Figure 3.9 displays the microcontroller board which each of the board pin diagram.

Figure 3.7： Arduino UNO R3 Microcontroller Board

Figure 3.8： Arduino UNO R3 Microcontroller Board

3.2.6 Servo Motor

Servo motors been used in this project as it is the mose efficient motor to be used.It its because it it easy to place the motor shaft at any position by using the control signal.The motor shaft can be hold at specific point unless the control signal bee nchanged. This is valuable when it comes to controlling arms of robos, objects to move in specific angle and etc. Servo motors are categorized with many different sizes or torque as it tolerates with different sizes of servos .Servo motors wit arms normally are linked to the objecy and it will required it to move in different angle.The servo motors shown in Figure 3.10 .

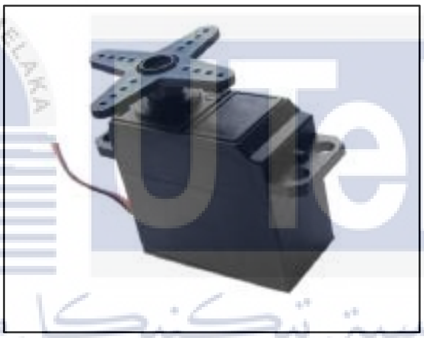


Figure 3.9 : Servo Motor

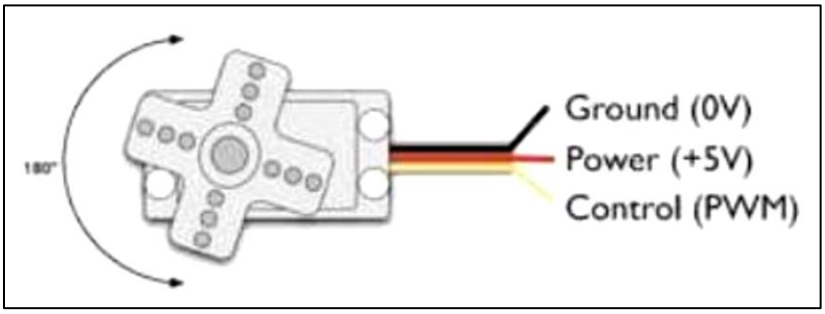


Figure 3.10 : Servo Motor

Figure 3.11 shows that there are three different wires with different output. The third pin acts as to receive control signal which is a PWM (pulse width modulation) signal. [29].This will accept the signal produced by the controller and transmit the data to turn on its angle based on the signal produced by the microcontroller. The control signal is much simpler compared to motor such as stepper motor.

Figure 3.11 : Inner Part Servo Motor

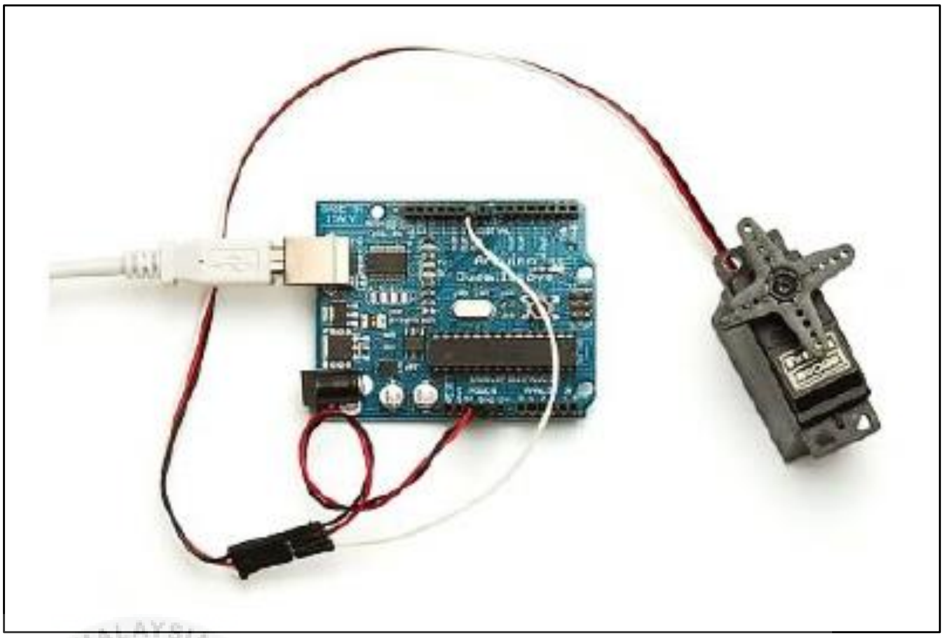


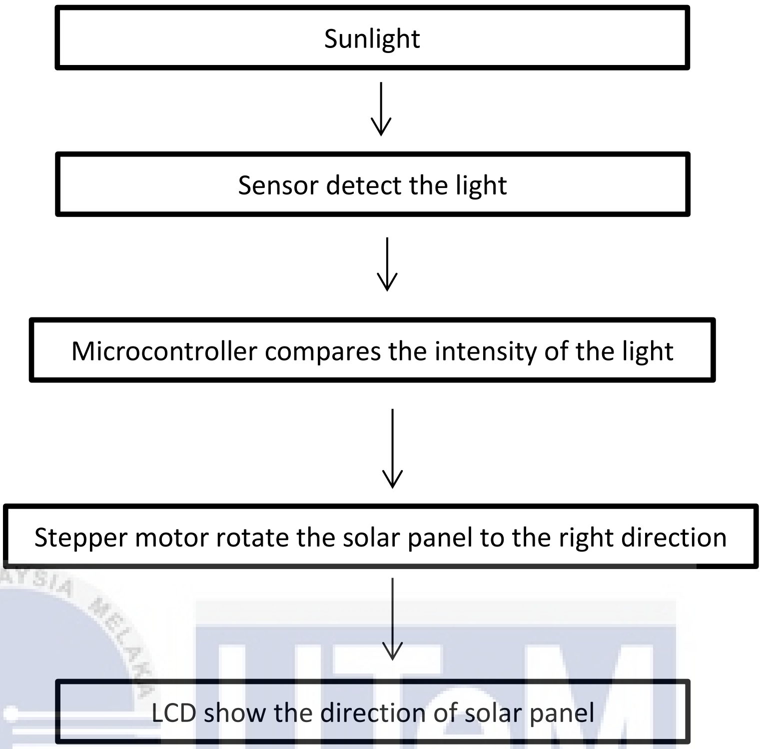
Figure 3.12 : Servo Motor Connected Arduino

3.3 Procedure

3.3.1 Overall Flow Chart

The process of selecting the title will be the very first step and following of each different action in the overall flow chart. It includes as well as the project finding and the results obtained from the experiments. The flow chart occurs when positioning the solar panel using microcontroller as in dual axis solar tracker. This causes the solar panel to be aligned to determine the sun position to arrange its direction in the straight line with the vertical axis direction of the solar panel. The microcontroller proceeds back again the step if the sun is not effectively facing the tracker.

Lastly, the ends of the flow chart will shows the data been analysis from the tests performed on this project.

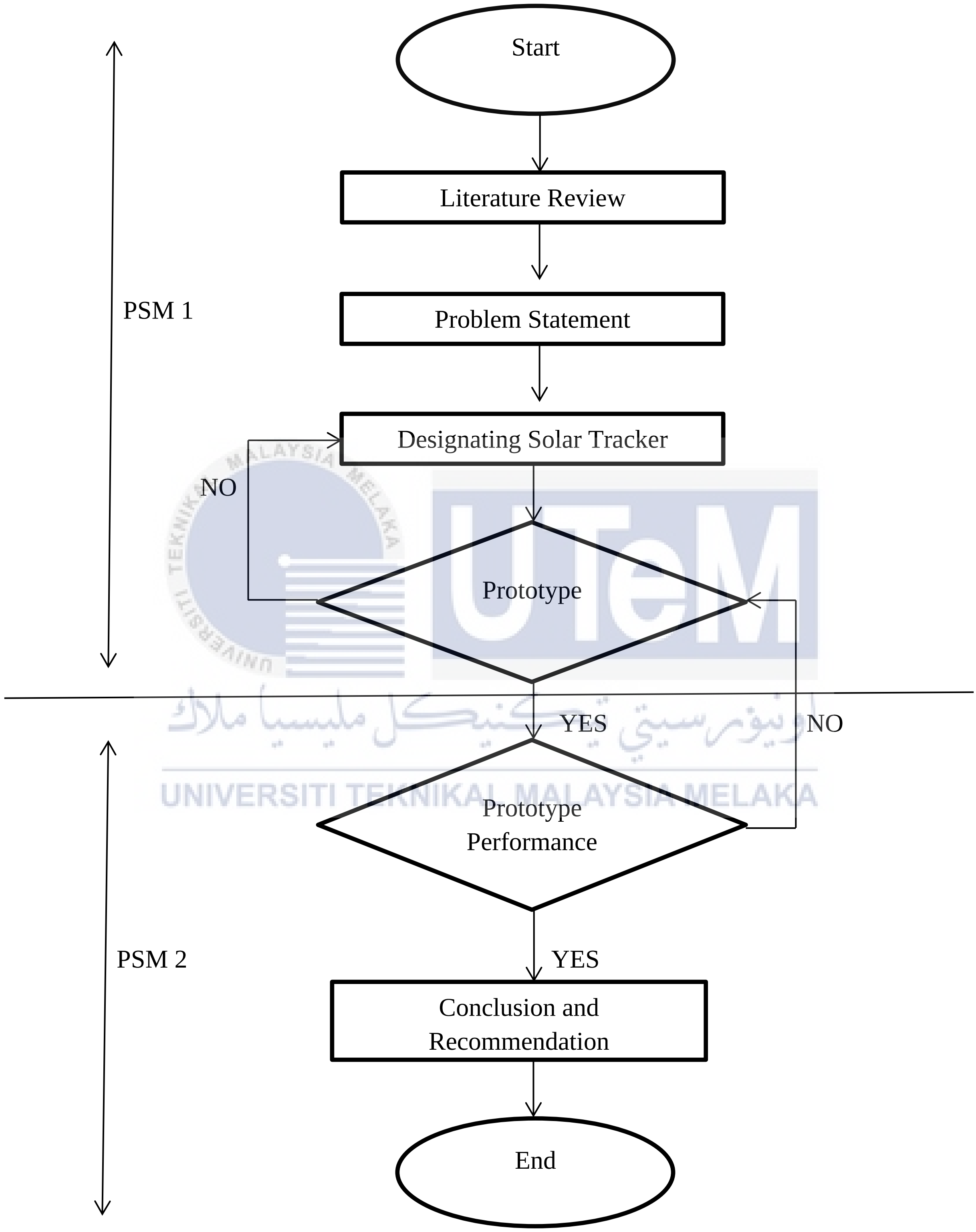


Flowchart 3.4: The flow chart for overall project

The explanation begins when the sun was transmitted to the system by light ray. If there is no light detected, the system will remain in standby mode. Then, the sensor will detect the presence of light and direct data to the microcontroller as it collect data of each analog pin.

Then, the microcontroller now will sense which intensity is higher on each of the analog pin that been obtained and send the data to the servo motors. The servo motors then will rotate its solar panel based on the data transmitted. The direction will be based on the date gathered on the microcontroller.

3.3.2 Process of Final Year Project



Flowchart 3.4.2: The flow chart for overall project

3.4 Experimental Setup

The main objective that has to be achieved in this project is to design dual axis solar tracker that move independently in X and Y direction to track maximum energy. Thus, the experiments were set up to fulfil the objectives of this project. First of all, check first all the connections and make sure the connection is all connected between the terminal boxes.

The tracking and non-tracking experiments been conducted every one hour interval between 8.00 a.m. until 5 p.m., total of 9 hours of operation in harvesting the solar energy. The experiment was conducted 3 times in 3 different days to ensure the value obtained is persistent. The figure 3.13 shows that the tracker is capturing solar energy located at Universiti Teknikal Melaka Malaysia (UTeM). Then, take a digital multimeter and switch the dial to direct- current volts to measure the current produced by the solar panel when it is generating it’s maximum power. With the same solar panel, measure the voltage between the positive and negative terminals.

Figure 3.13 : Measurement of Voltage

Then, the next experiment was conducted to measure the LDR (light dependent resistance). It is tested by using a digital multimeter. This experiment is to prove that the resistance of an LDR varies according to the light intensity that falls on it.

Figure 3.14 : Measurement of Photoresistor

For a proper diagnosis, the resistance been measured in bright and darkness light condition. Firstly, keep the multimeter at Ohms mode. The LDR have to be subjected towards bright source of light. Then, connect the LDR into the multimeter terminals as shown in the figure 3.14.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Introduction

In this chapter of Result and Discussion, there will important finding result when the experiment was carried out. The result will be collected based on the input power collected on each different panel which are stationary panel and also the solar tracking system which is in single or dual axis tracker. This is to shows and identifies the differences of each efficiency of collecting solar energy whether there are any differences of increasing or decreasing in terms of efficiency, power, voltage and strength of light intensity.

4.2 Connection of Terminal Block

The common positive which is the red wires. Total of four red wires that will be coming out from the sensors will be twisted together and put in a one terminal block itself in figure 4.1.

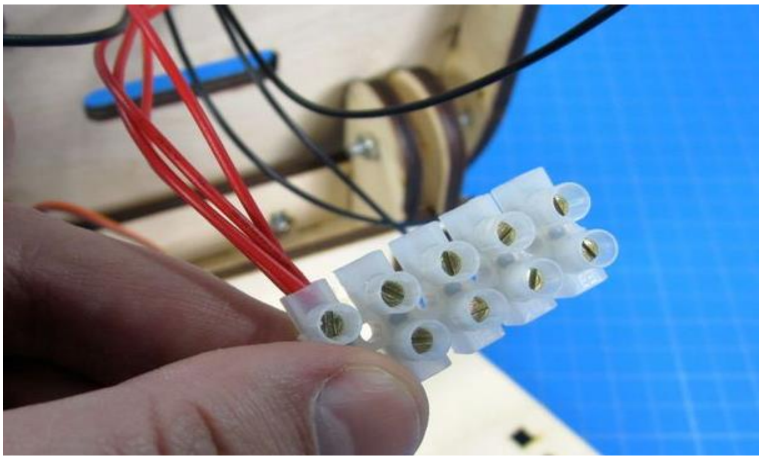


Figure 4.1

Then, each of the remaining black wire will be carefully inserted in each of the terminal block hole that is coming from the sensor shows in Figure 4.2.

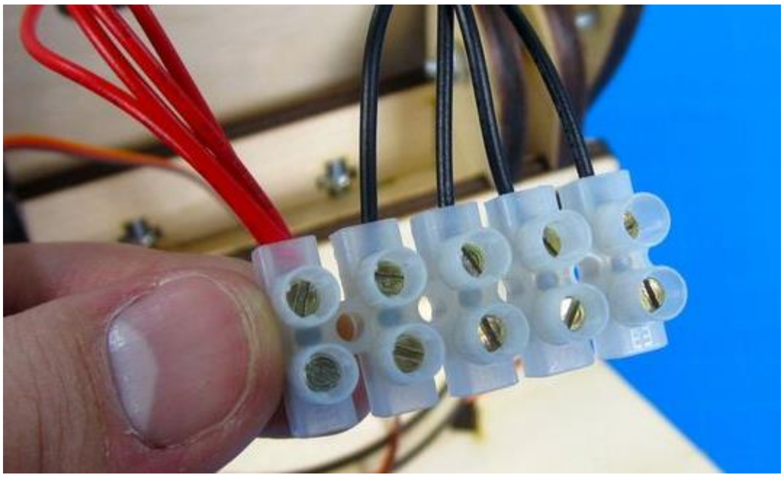


Figure 4.2

The four resistors value of 10,000 ohm will be twisted together to put in one hole together shown in figure 6.3. Jumpers will be then shared a hole with a resistor on the 5 port block. Jumper here acts as a common negative shown in figure 4.3.

Figure 4.3

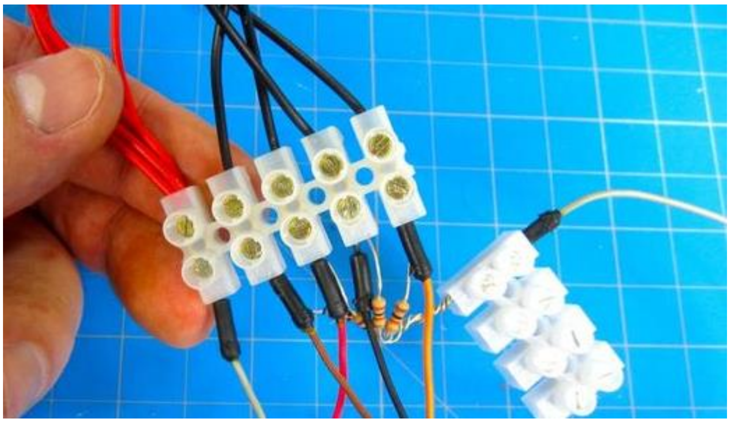


Figure 4.4

Figure 4.4 shows that each of the wire will be then inserted into arduino of every analog pin which provide different signal

Figure 4.5

When each of the pins been inserted as shown in Figure 4.5, then we can run the microcontroller and test the coding. The pin is inserted based on the numbering to align with the coding. Each of the signals as well can be changed if the coding was changed. It is based on the codes that been setup in the software as the data will be transmitted according to the coding.

4.3 Attachment of Servo motor

This project involves two standard servo motor that rotate approximately 180 degrees. This will be controlled by Arduino Servo Library. The limits been implemented in the Arduino to limit its movement once both of the servo reached their limitation of angle. To keep the gear from turning past its limits, the limitation been tested by changing the angular position which changes the servo position. This is to keep the prototype to be damaged.

The servo motor will move the solar panel towards the LDR where the resistance will be low .It will keep following the light and track it. If there’s a same amount of light falling on the LDR, then the servo will remain static and not moving. The LDR will change its resistance if it rotates towards lower resistance. Both servo acts on different direction shown in Figure 4.6. The servo 1 will move in vertical axis where the servo 2 will move in horizontal axis .This will help to make the solar tracker to be in two degree of freedom.

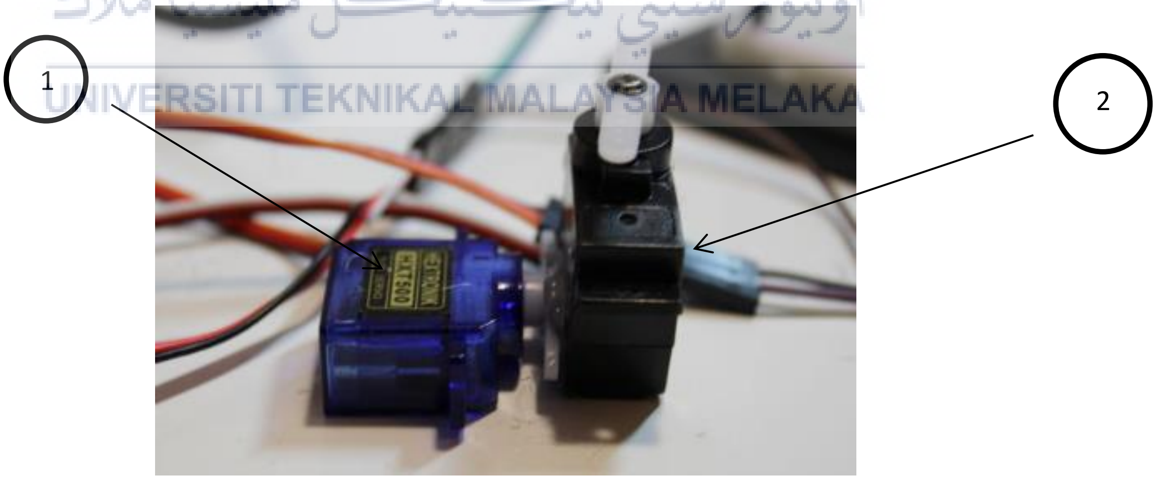


Figure 4.6: Servo Motor

4.4 Block Configuration of LDR

The solar tracker control system is designed to take and track light measurement from the light beamed from the east and west or south to north side. Each of the LDR here will actuate the panel tracker based on the light intensity and transmit the data to microcontroller. The four ldr will be shadowed by the designed block to ensure the detection of the correct of solar light intensity.

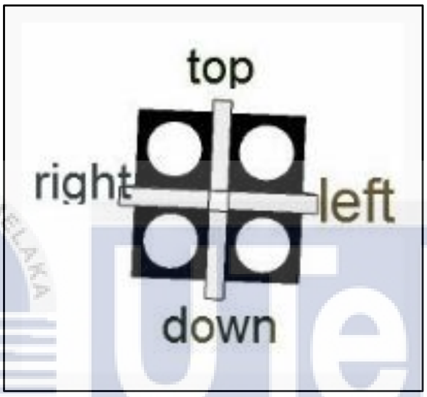


Figure 4.7

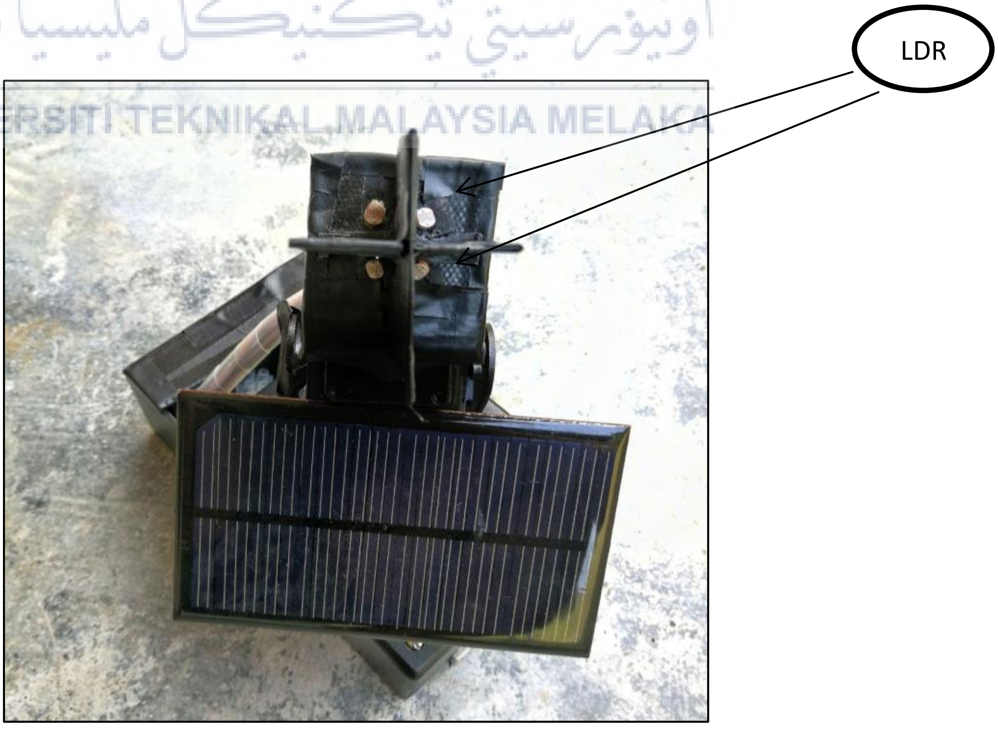


Figure 4.8

At the end of my PSM 1, I managed to complete my hardware and software. LDR managed to move on its own to track down the solar intensity and the servo able to rotate based on the data transmitted by the LDR. The coding as well been proved that it managed to function well based on the intensity of the light. The block diagram to shadow each of the LDR been designed correctly.

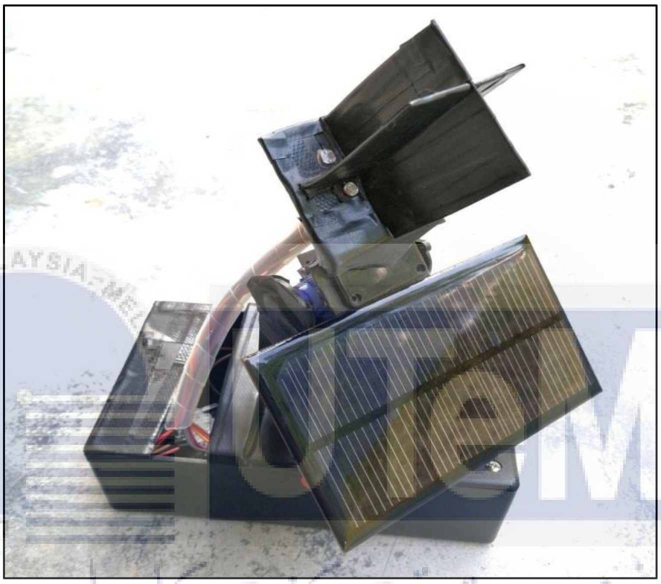


Figure 4.9

4.5 Coding

Servo motor control is controlled by the coding. It’s not supreme to route a motor with a varying voltage, so most controllers use to fake a different voltage for motor control by altering its speed without varying the voltage (that is, except for either full on or completely off). Every of the LDRs sensor will be measured and read by the Arduino to obtain the differences between two side of LDR in position of north and south for vertical and another two LDR in position of east and west for horizontal movement. Then, the difference between these two LDR sensors will be used as a feedback input to the Arduino to make a decision whether the motor should rotate in clockwise or counter clockwise or in static rotation.

When the feedback input is bigger than the positive sign, the motor should rotate in a long period of time towards clockwise. If the value obtained is small value then the motor will be static since the coding that been stated if the feedback input too small, the motor will be stopped. The horizontal and vertical been set up as 90 degree as its maximum displayed in the Figure 4.10 to limit its orientation.

Servos have a shaft that turns to specific position based on its control line. Frequency is precise to be able to control a specific servo. A characteristic servo motor supposes to be updated every 20 ms with a pulse in the middle of 1 ms and 2 ms, or in other words, among a 5 and 10% duty cycle on a 50 Hz waveform. With a 1.5 ms pulse, the servo motor will be at the original 90 degree position, with a 1 ms pulse, the servo will be in position of 0 degree position, and with a 2 ms pulse, the servo will be at 180 degrees. The four LDR acts as a signal to be placed in the Arduino signal as an analog pin.

```
#include <Servo.h> // include Servo library

#include <Servo.h> // include Servo library

Servo horizontal; // horizontal servo
int servoh = 90; // stand horizontal servo

Servo vertical; // vertical servo
int servov = 90; // stand vertical servo

// LDR pin connections
// name = analogpin;
int ldrlt = 0; //LDR top left
int ldrrt = 1; //LDR top rigt
int ldrld = 2; //LDR down left
int ldrrd = 3; //ldr down rigt

void setup()
{
  Serial.begin(9600);
```

Figure 4.10

Looping initiates in Figure 4.1.1. This function does precisely loops consecutively, allowing your program to modify and respond. It is used to actively control the Arduino board. Formula declaration are been setup in the coding as an average of each side of the photoresistor board.

When the LDR1 is receiving the light source in position 1 (left and bottom), then the Arduino is receiving the signal from the LDR1 .Hence, the Arduino will direct the signal to both of DC motors. The first DC motor (bottom) will rotate anticlockwise and the second DC motor (top) will also turn anticlockwise. The similar thing will occur when the LDR2 is receiving the light source in position 2 (right and bottom). This is caused from the coding that has been set in the software part. For position 3, when the LDR4 is getting the light source (right and top), same thing take place to the Arduino which is receiving the signal from LDR4 then the Arduino will transmit the signal to both of DC motor.

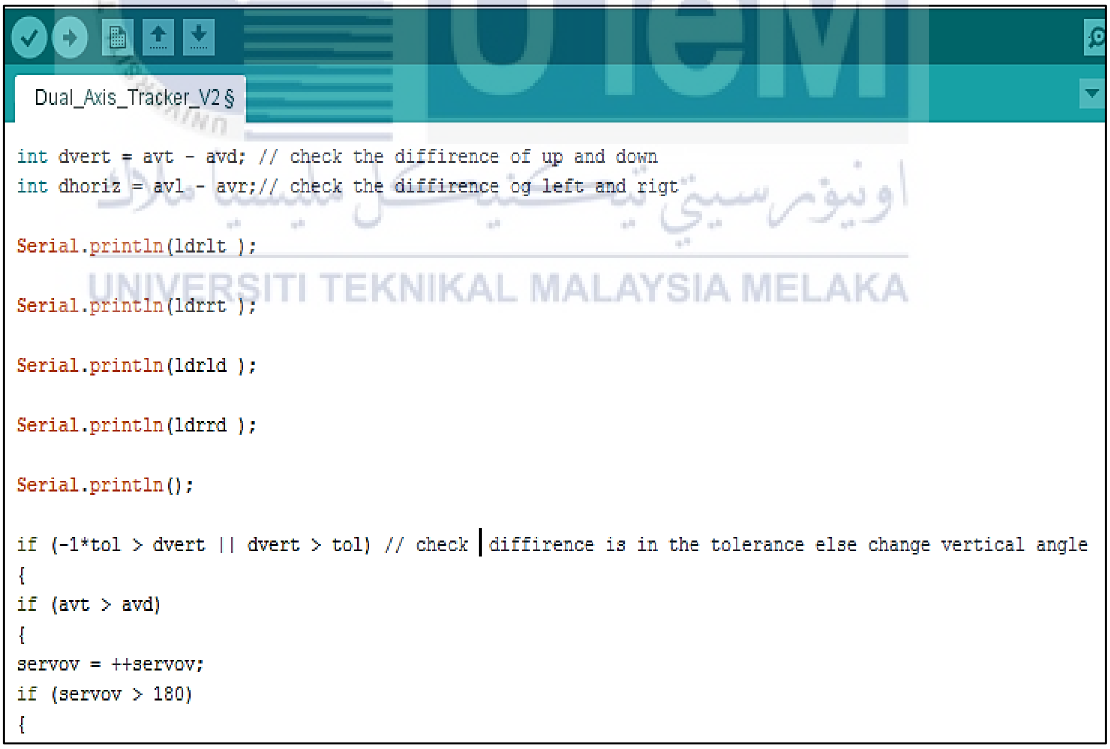


Figure 4.11

The IF else tolerates better control over the flow of the code than the basic. The IF statement lets numerous tests to be assembled together and if its not achieve the definite target it will go to Else. Else will be executed if the condition in the IF statement results is false .It can be advance to another IF test, so that it will be mutually select tested. The Else will be executed IF one is present as displayed in Figure 4.13 and 4.14.

Dual_Axis_Tracker_V2 §

```
servov = 180;
}
}
else if (avt < avd)
{
servov= --servov;
if (servov < 0)
{
servov = 0;
}
}
vertical.write(servov);
}

if (-1*tol > dhoriz || dhoriz > tol) // check if the diffirence is in the tolerance else change horizontal angle
{
if (avl > avr)
{
servoh = --servoh;
if (servoh < 0)
{
servoh = 0;
```

Figure 4.12

Dual_Axis_Tracker_V2 §

```
servoh = --servoh;
if (servoh < 0)
{
servoh = 0;
}
}
else if (avl < avr)
{
servoh = ++servoh;
if (servoh > 180)
{
servoh = 180;
}
}
else if (avl == avr)
{
// nothing
}
horizontal.write(servoh);
}
delay(dtime);
}
```

Figure 4.13

4.6 Schematic Diagram

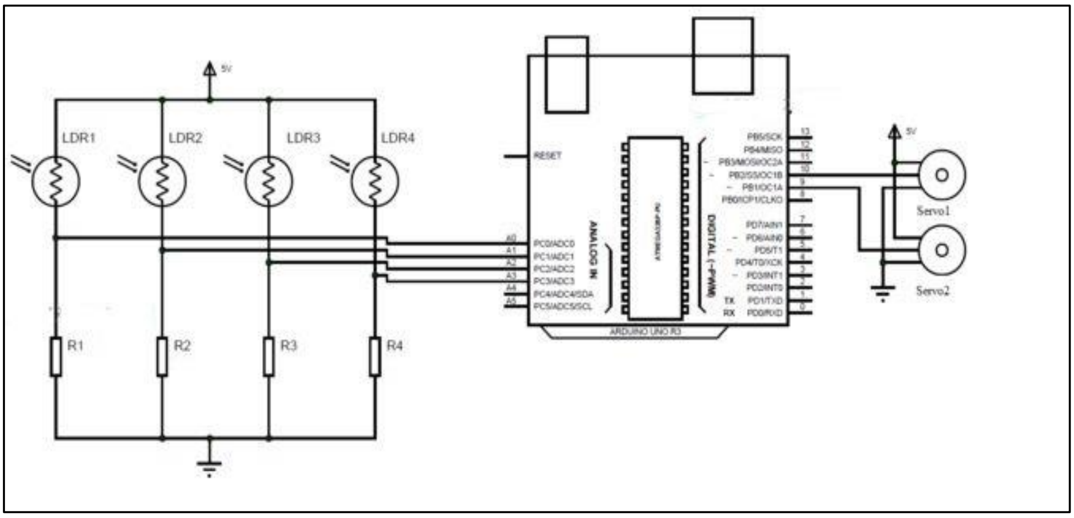


Figure 4.14: Schematic Wiring

As you can see here in Figure 4.15, it is a wiring diagram. The servo motor been attached to the Arduino as each of the pins will be put in according to the signal been set up in the coding. The bottom servo will goes to Pin 10 and the Top servo will goes to Pin 9. Since the servo have three wire coming out from it , it need to be hooked up correctly as the red wire will goes to positive port, the black will goes to negative port and the yellow wire will goes to the signal port.

The diagram with the LDR and resistor been set up as a voltage divider on the left side of the schematic diagram to measure the voltage difference. In PSM 2, it will be recorded and measured to see the result as changes of LDR resistance will causes changes of voltage with different angle of incident.

Thus, the common negative that been attached together from the five port block will go into the Ground pins as the common positive from the four port block will go to the 5V pins. The four LDR (light dependent resistors) must be positioned with different shaded angle. The block configuration designed with four different shaded areas will go to each of the common negative.

The Top Left will goes to Pin 2, the Bottom Left will goes to Pin 0 , the Top Right will goes to Pin 3 and the Bottom Right will goes to Pin 1. This is based on the coding setup as we can change as well the pin number in the coding. The operation enables the system to track the sun over a dual axis movement.

4.7 LDR (Light Dependent Resistor) Reading

The four LDRs sensor is fixed on top of the solar PV panel. It is then fixed to Arduino analog pins and been placed with four different position covered with walls. This sensor will detect the light intensity of the light and will act as proportional controller when being torched with light. As shown in figure 4.15, the configuration of the LDR sensors in four different place. The experiment been conducted when the light been torched on the Top Right position.

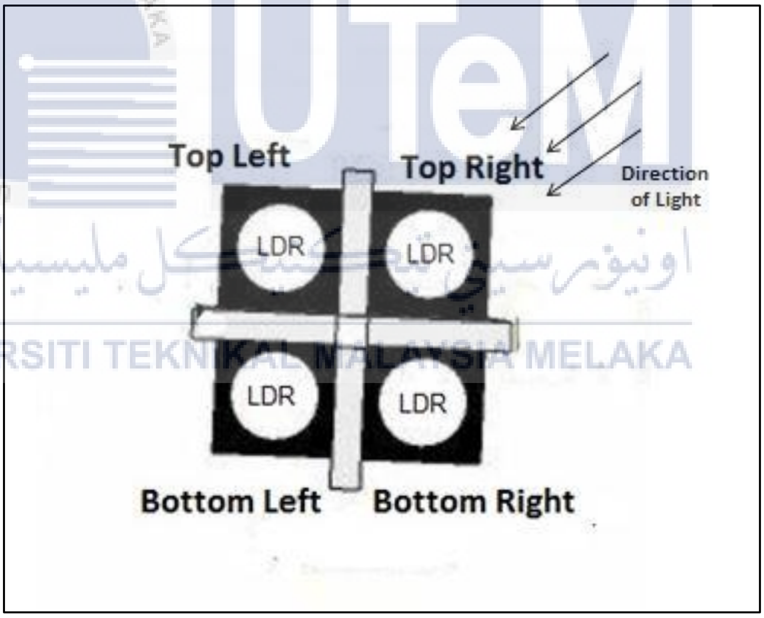


Figure 4.15: LDR diagram

Comparison of light intensity that been detected by the LDRs is been compared by using 10k ohm resistor which act as a proportional controller. The configuration of the LDR sensor will be located on a voltage divider circuit where the sensor is fixed in series with resistor that will be shown in figure 4.15.

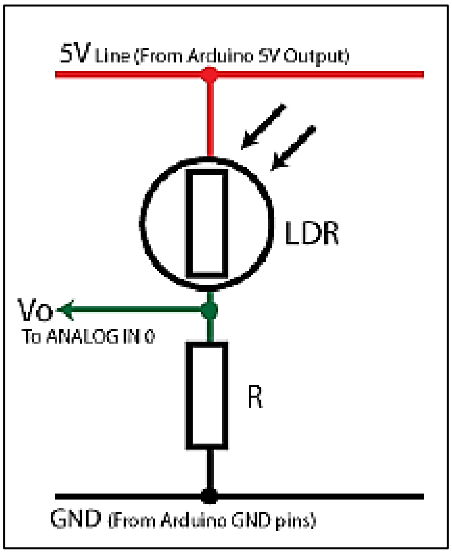


Figure 4.16: Voltage Divider

The output voltage of LDR is been calculated according to the equation of voltage divider,

$$\mathrm{Vi} = Vcc\,\frac{Ro}{LDR+Ro} \qquad (1)$$

The photoresistor resitance been measured based on the the different light intensity with different position of the LDRs. The voltage across resistance been calculated based on the equation (1) .

Light Intesity	LDR Position	Photoresisor (ohm)	Voltage across Resistance
Very Dim	Bottom Left	800,000	0.062
Dim	Top Left	70,000	0.625
Bright	Bottom Right	1500	4.348
Very Bright	Top Right	300	4.854

Table 4.7 Photoresistor measurement

Position of the LDR at Top Right receives the highest amount of light therefore the value of voltage is the highest among other sensor. Reading for position Bottom Left, Top Left and Bottom Right taken are lower because the light intensity is not as high as the Top Right. It is shown that the higher the light intensity, the lower its photoresistor reading.

Then, the data in table 4.7 been visualised in a graph form in figure 4.18 It is shown that the higher the light intensity, the lower of its photoresistor reading. The comparison has been made between actual LDR reading theoretically and the measurement one in figure 4.17 and figure 4.18.

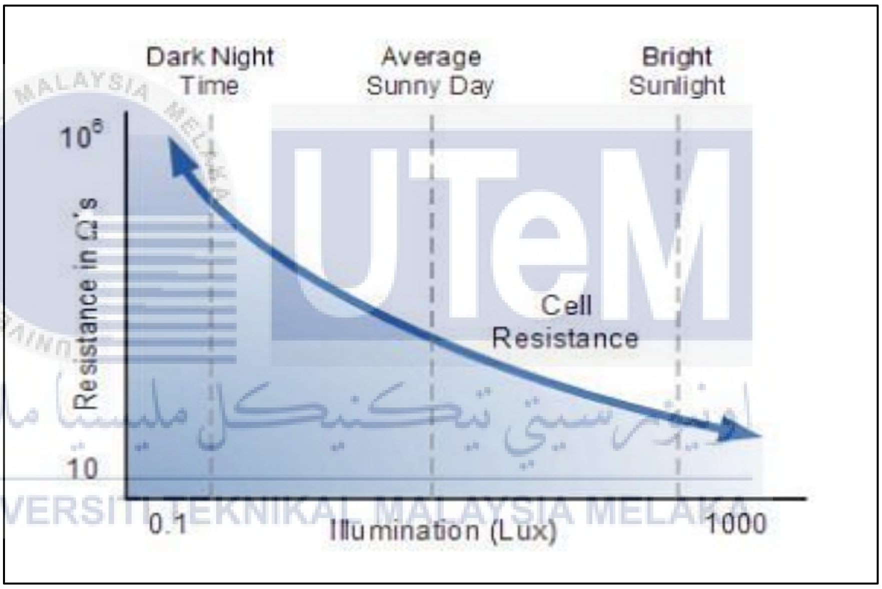


Figure 4.17: Actual LDR Resistance Variation Graph (30)

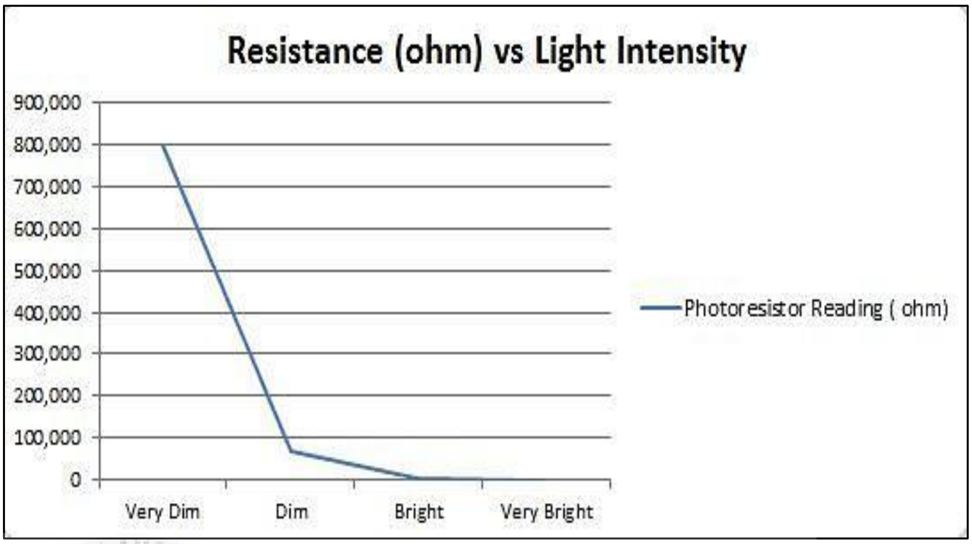


Figure 4.18: Measured LDR Resistance Variation Graph

The graph plotted shown that resistance is decreased when the light falls on them and it is increased when in dark condition. When a light dependent resistor is kept in dark, the resistance is very high. On the other side, when

4.8 Results and Discussion

The next experiments been carried out by getting the input voltage collected from solar energy between tracking and non-tracking. Therefore, all the data were tabulated and recorded in three different days as shown in the figure 4.19 to 4.24. The main parameters for the experiments were voltage and current across the solar panel.

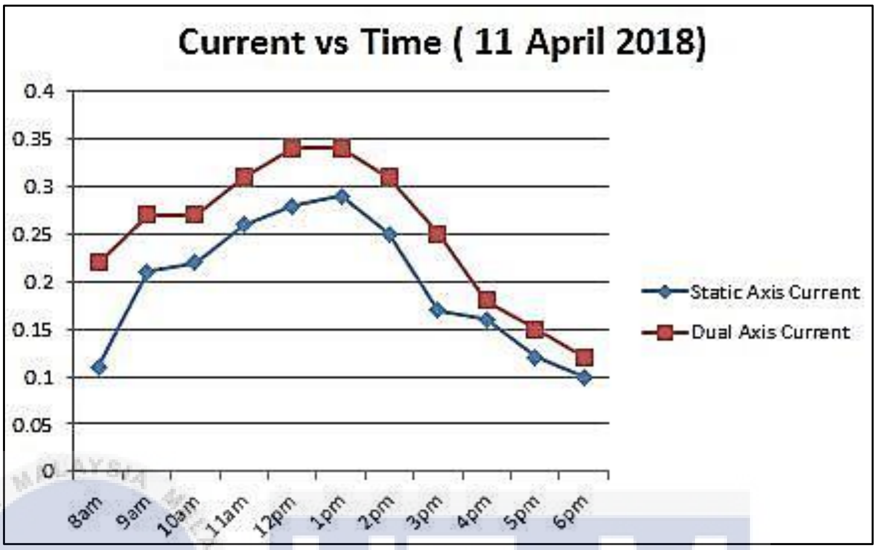


Figure 4.19: Graph of current results obtained on 11th April 2018

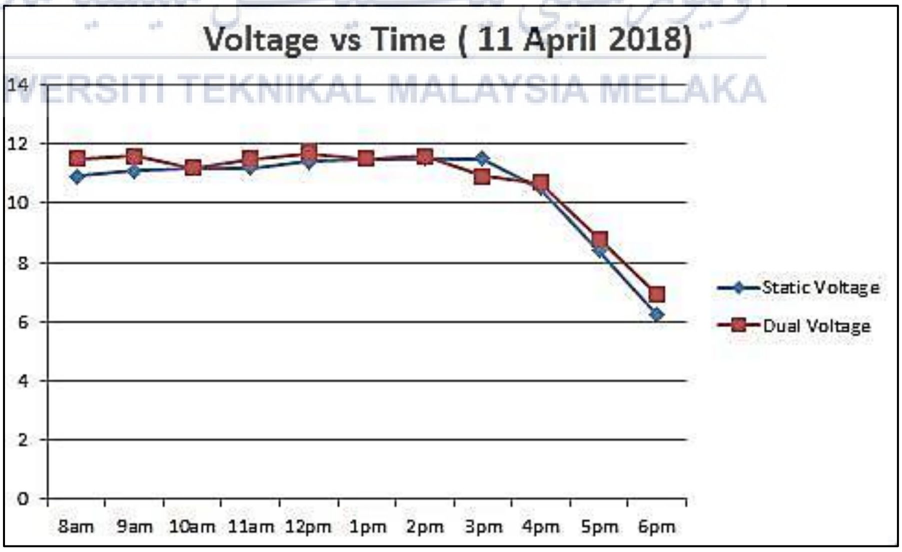


Figure 4.20: Graph of voltage results obtained on 11th April 2018

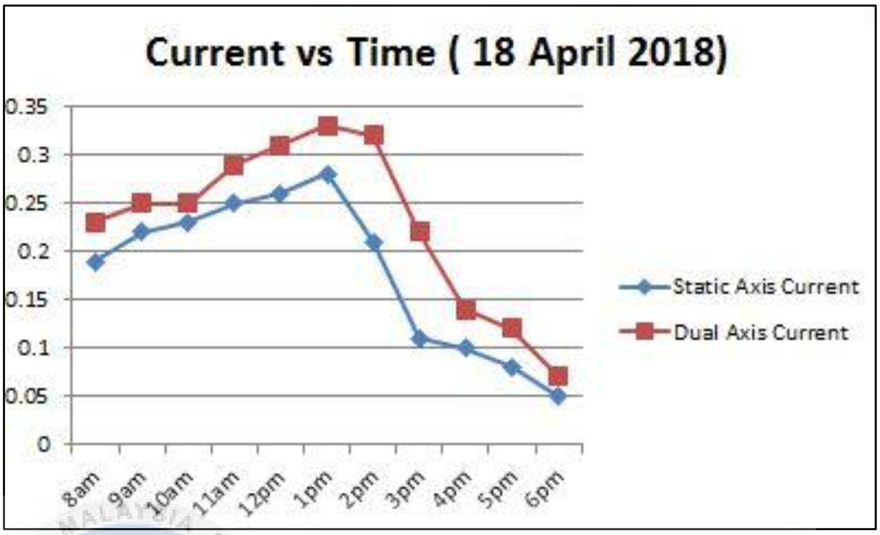


Figure 4.21: Graph of current results obtained on 18th April 2018

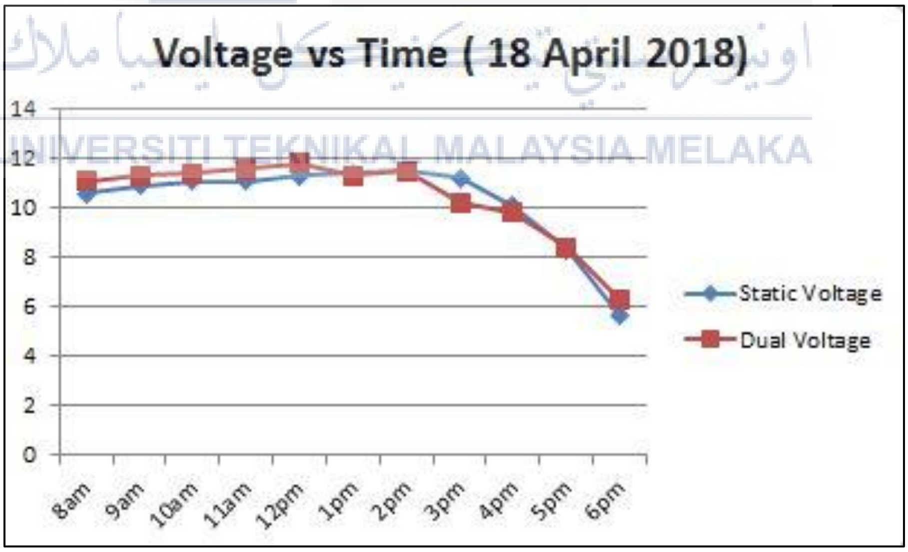


Figure 4.22: Graph of voltage results obtained on 18th April 2018

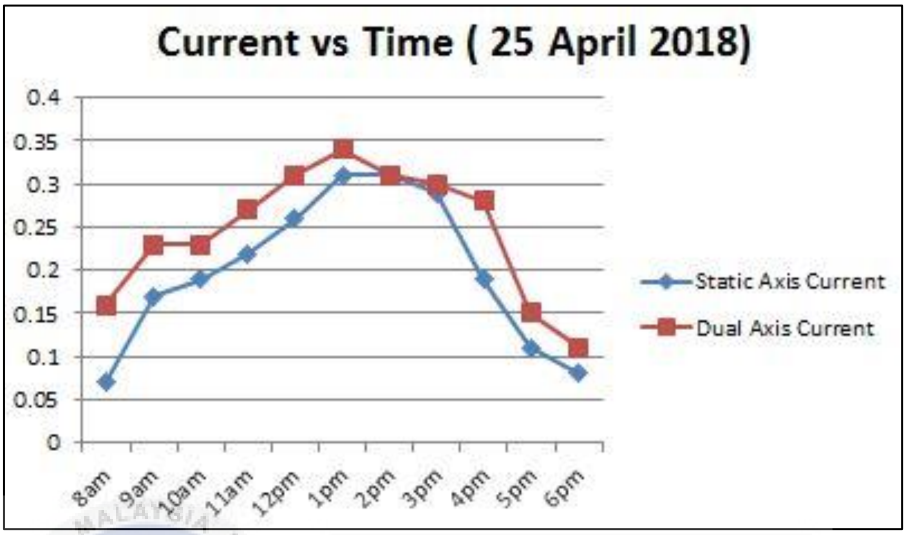


Figure 4.23: Graph of current results obtained on 25th April 2018

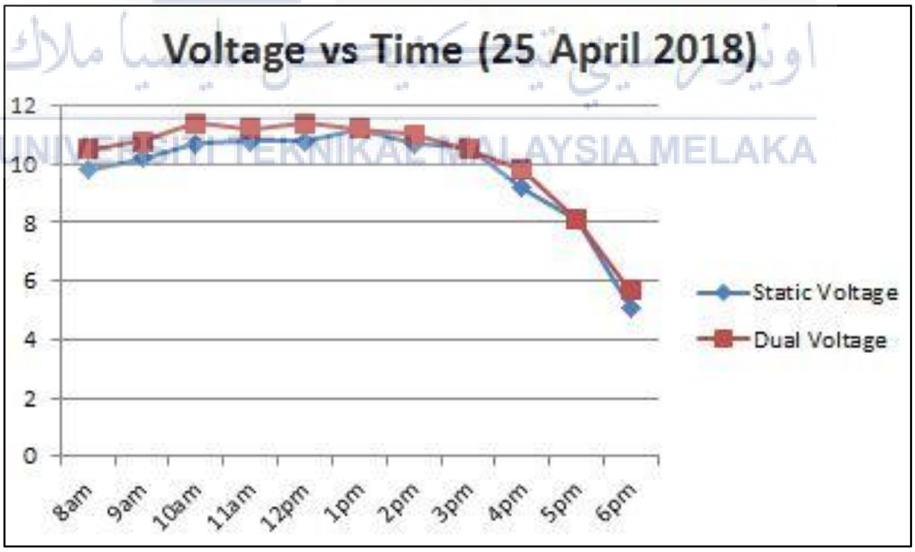


Figure 4.24: Graph of voltage results obtained on 25th April 2018

From the graph taken by three different days, it can be seen that there is much improvement in current and voltage starting from 8.00 am in tracking panel compared to static panel. It can be seen that the maximum sunlight occurs at around midday, with maximum values obtained between 11.00am and 2.00pm. In the morning and late evening, intensity of sunlight diminishes and decreased and the values obtained are lower than those obtained during the day time.

The panel will be facing the sun when it is perpendicular towards the sun as the LDRs receive the same amount of light. When the time goes by, these two measurements decrease down around 2.00 pm. The highest current of static panel and tracking panel is at 1.00 pm. In this case of voltage, the voltage variation is lesser compare with current result because the voltage has no direct relation with sun light intensity.

Next experiments were carried out to compare the input power collected by the solar energy between tracking and non-tracking. The data recorded and tabulated as shown in figure 4.25 to 4.30.

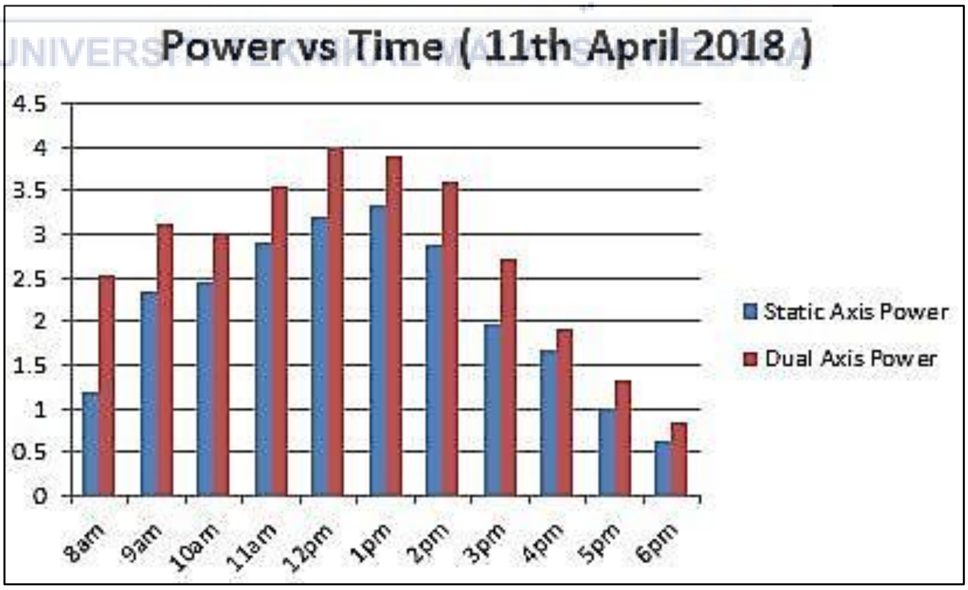


Figure 4.25: Bar chart of power results obtained on 11^{h} April 2018

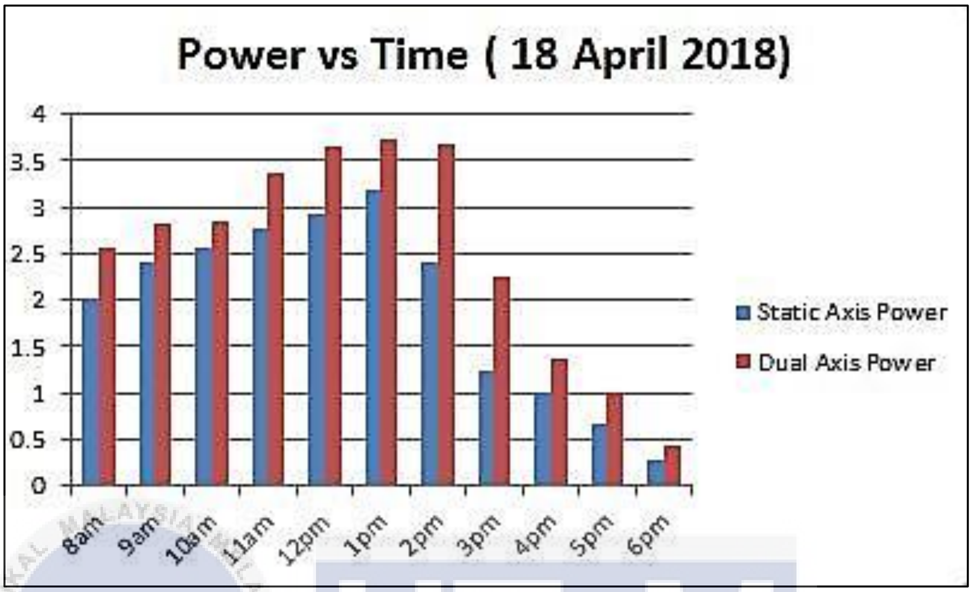


Figure 4.26: Bar chart of power results obtained on 18th April 2018

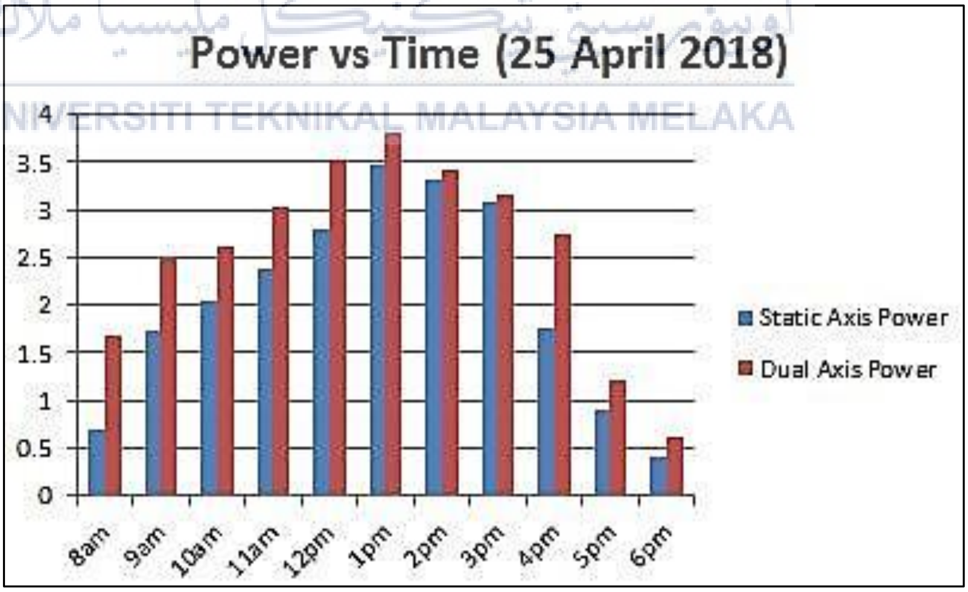


Figure 4.27: Bar chart of power results obtained on 25th April 2018

The graphs for three days shows that solar tracking system with intelligent method which is dual tracking has better results of power compared to a stationary panel (non-tracking). The input power collected in three days is not constant as it varies depending on the weather.

The three days have almost similar input power since the weather on these days is quite sunny and hot. Hence, a solar tracking system with intelligent method (dual axis) is able to increase the input power collected compared to a stationary panel. By using the trackers, the power gained (efficiency) is been measured using the formula in (2).

$$\text{Efficiency} = \frac{Pt - Ps}{Pt}\ (100\ \%) \tag{2}$$

Where Pt stands for tracking system for solar tracking dual system mode and Ps stands for solar tracking stationary panel mode.

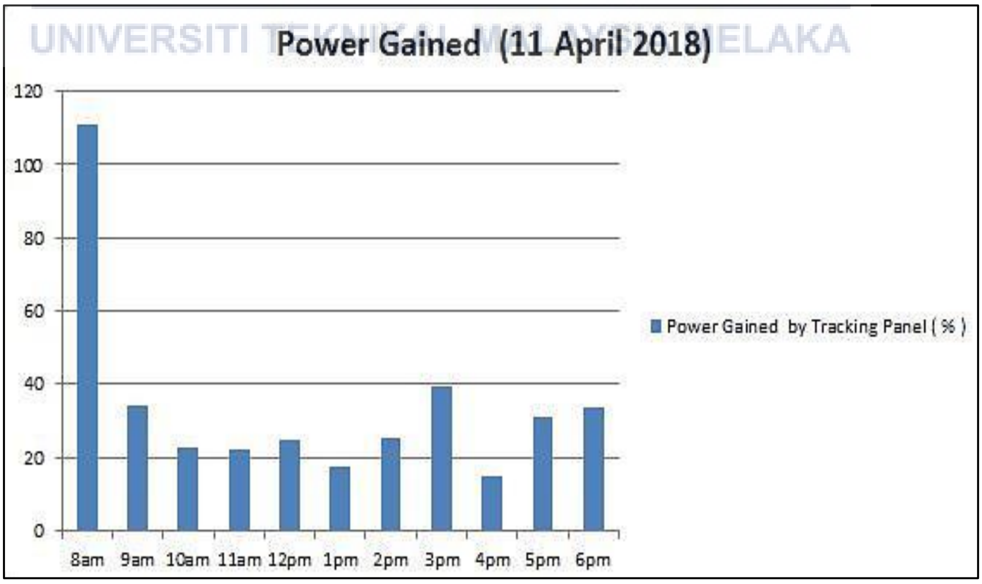


Figure 4.28: Bar chart of power gained results obtained on 11h April 2018

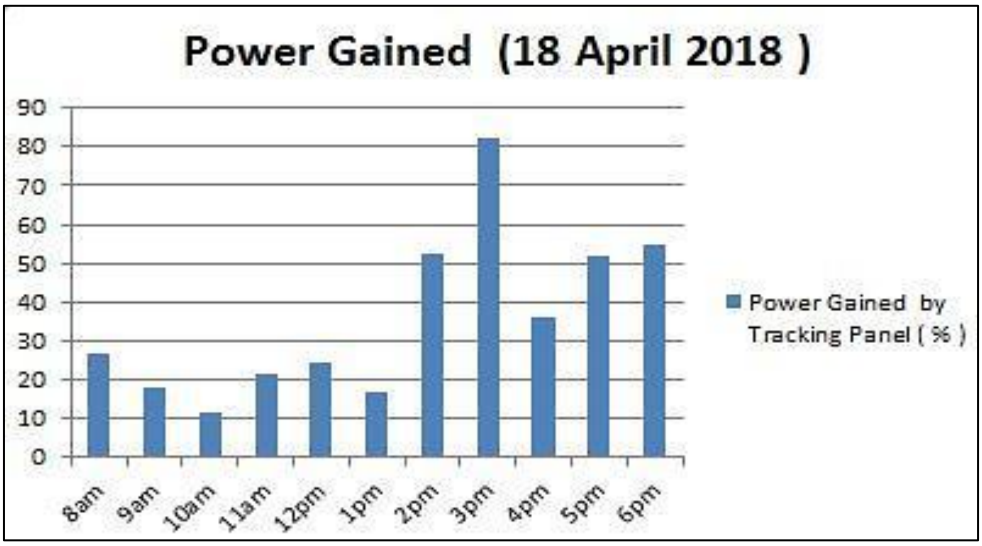


Figure 4.29: Bar chart of power gained results obtained on 18th April 2018

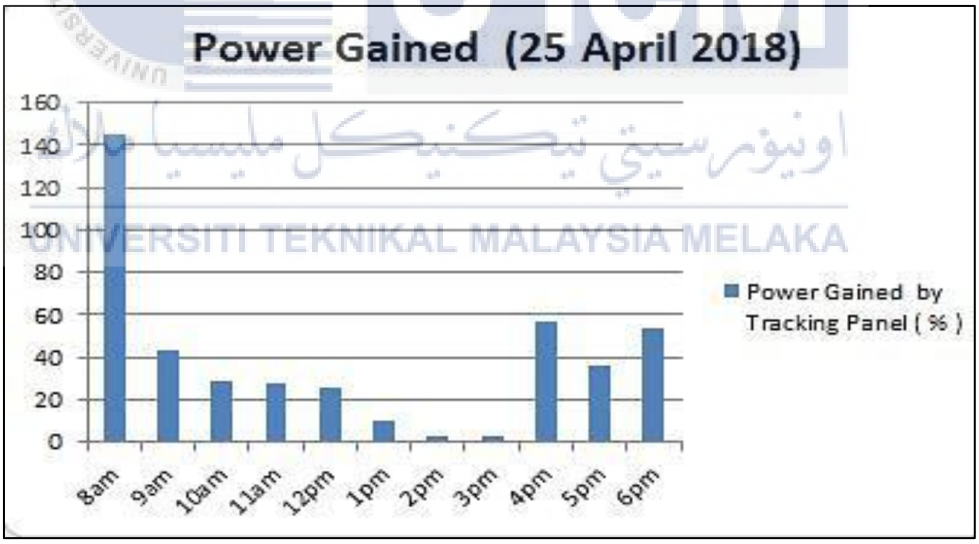


Figure 4.30: Bar chart of power gained results obtained on 25th April 2018

The power gained achieved in the morning is much more compared to the afternoon and evening since the tracking system can accurately track the sun light at these times while the static solar panel could not track it. It is low for power gained on the 18th April 2018 because it is cloudy that period of time and the weather is unstable on that particular day. The bar chart proven that solar tracking dual axis is able to track more with better efficiency of harvesting solar energy comparing to single axis solar tracker.

CHAPTER 5
CONCLUSION

5.1 Conclusion

In a nutshell, it can be concluded that solar tracker have been industrialized to increase and improve the power that will be generated by the solar panel as the sun move across the sky .A microcontroller which is Arduino is been used to control the movement of solar panel to move in certain angle and position. The system is generally designed such that energy will keep produced by the solar panel even though there are weather disturbances. The readings obtained are noted down precisely during the project to decrease the errors as many as possible so that the reading can be much more accurate. Solar energy is now leading as it mostly used renewable sources nowadays. It is being widely used and within some more years it will be very popular that it will be implemented for many purposes, in industries and household as well. So it is most important fact to utilize the maximum energy of the sun so that maximum power can be generated. In a lot of places, research is being done on this fact how it is possible to make full use of the day light. This project gives good impacts and positive scope in future. The accuracy of the solar panel thus improved and the steps taken was managed to be completed to get the best accurate desired output. As per energy alarmed, solar energy is one of the most favourable energy which is going to be a leading source of energy in near future. A budget cost effective intelligent sun tracking system to abstract maximum output solar energy has been designed.

5.2 Future Recommendations

In the future, there are several recommendations for future works planning as to improve the efficiency and performance of the solar energy. First of all, redesign the mechanism of the system as to make sure the solar PV panel gets the maximum and highest solar energy. The size of the solar PV panel needs to be bigger in size as to collect and harvest more solar energy. The parts of the model need to be redesigned especially the motor holder and the panel frame.

Other than that, the function of LDR sensors as input needs to be omitted in the future. This is to ensure the accuracy of the positioning of the solar PV panel can be increased in terms of maximum intensity of solar irradiance. The analysis need to be further up as to calculate the radiance of the solar energy and the angle of the azimuth and altitude to make the alignment of the solar panel with the position of the solar panel much accurate.

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APPENDIX A

Time	Static Axis Current (A)	Dual Axis Current (A)	Static Voltage (V)	Dual Voltage (V)
8am	0.11	0.22	10.9	11.5
9am	0.21	0.27	11.1	11.6
10am	0.22	0.27	11.2	11.2
11am	0.26	0.31	11.2	11.5
12pm	0.28	0.34	11.4	11.7
1pm	0.29	0.34	11.5	11.5
2pm	0.25	0.31	11.5	11.6
3pm	0.17	0.25	11.5	10.9
4pm	0.16	0.18	10.5	10.7
5pm	0.12	0.15	8.4	8.8
6pm	0.1	0.12	6.2	6.9

Current and Voltage (11th April 2018)

Time	Static Axis Power (W)	Dual Axis Power (W)	Power Gained by Tracking Panel (%)
8am	1.199	2.53	111.0092
9am	2.331	3.132	34.36293
10am	2.464	3.024	22.72727
11am	2.912	3.565	22.42445
12pm	3.192	3.978	24.62406
1pm	3.335	3.91	17.24138
2pm	2.875	3.596	25.07826
3pm	1.955	2.725	39.38619
4pm	1.68	1.926	14.64286
5pm	1.008	1.32	30.95238
6pm	0.62	0.828	33.54839
Average Power Gained			34.18158

Power Gained (11th April 2018)

Time	Static Axis Current (A)	Dual Axis Current (A)	Static Voltage (V)	Dual Voltage (V)
8am	0.19	0.23	10.6	11.1
9am	0.22	0.25	10.9	11.3
10am	0.23	0.25	11.1	11.4
11am	0.25	0.29	11.1	11.6
12pm	0.26	0.31	11.3	11.8
1pm	0.28	0.33	11.4	11.3
2pm	0.21	0.32	11.5	11.5
3pm	0.11	0.22	11.2	10.2
4pm	0.1	0.14	10.1	9.8
5pm	0.08	0.12	8.3	8.4
6pm	0.05	0.07	5.7	6.3

Current and Voltage (18th April 2018)

Time	Static Axis Power (W)	Dual Axis Power (W)	Power Gained by Tracking Panel (%)
8am	2.014	2.553	26.76266
9am	2.398	2.825	17.80651
10am	2.553	2.85	11.63337
11am	2.775	3.364	21.22523
12pm	2.938	3.658	24.50647
1pm	3.192	3.729	16.82331
2pm	2.415	3.68	52.38095
3pm	1.232	2.244	82.14286
4pm	1.01	1.372	35.84158
5pm	0.664	1.008	51.80723
6pm	0.285	0.441	54.73684
Average Power Gained			35.96973

Power Gained (18th April 2018)

Time	Static Axis Current (A)	Dual Axis Current (A)	Static Voltage (V)	Dual Voltage (V)
8am	0.07	0.16	9.8	10.5
9am	0.17	0.23	10.2	10.8
10am	0.19	0.23	10.7	11.4
11am	0.22	0.27	10.8	11.2
12pm	0.26	0.31	10.8	11.4
1pm	0.31	0.34	11.2	11.2
2pm	0.31	0.31	10.7	11
3pm	0.29	0.3	10.6	10.5
4pm	0.19	0.28	9.2	9.8
5pm	0.11	0.15	8.1	8.1
6pm	0.08	0.11	5.1	5.7

Current and Voltage (25th April 2018)

Time	Static Axis Power (W)	Dual Axis Power (W)	Power Gained by Tracking Panel (%)
8am	0.686	1.68	144.898
9am	1.734	2.484	43.2526
10am	2.033	2.622	28.97196
11am	2.376	3.024	27.27273
12pm	2.808	3.534	25.8547
1pm	3.472	3.808	9.677419
2pm	3.317	3.41	2.803738
3pm	3.074	3.15	2.472349
4pm	1.748	2.744	56.97941
5pm	0.891	1.215	36.36364
6pm	0.408	0.627	53.67647
Average Power Gained			39.293

Power Gained (25th April 2018)

APPENDIX B

Arduino Code to Servo Motors

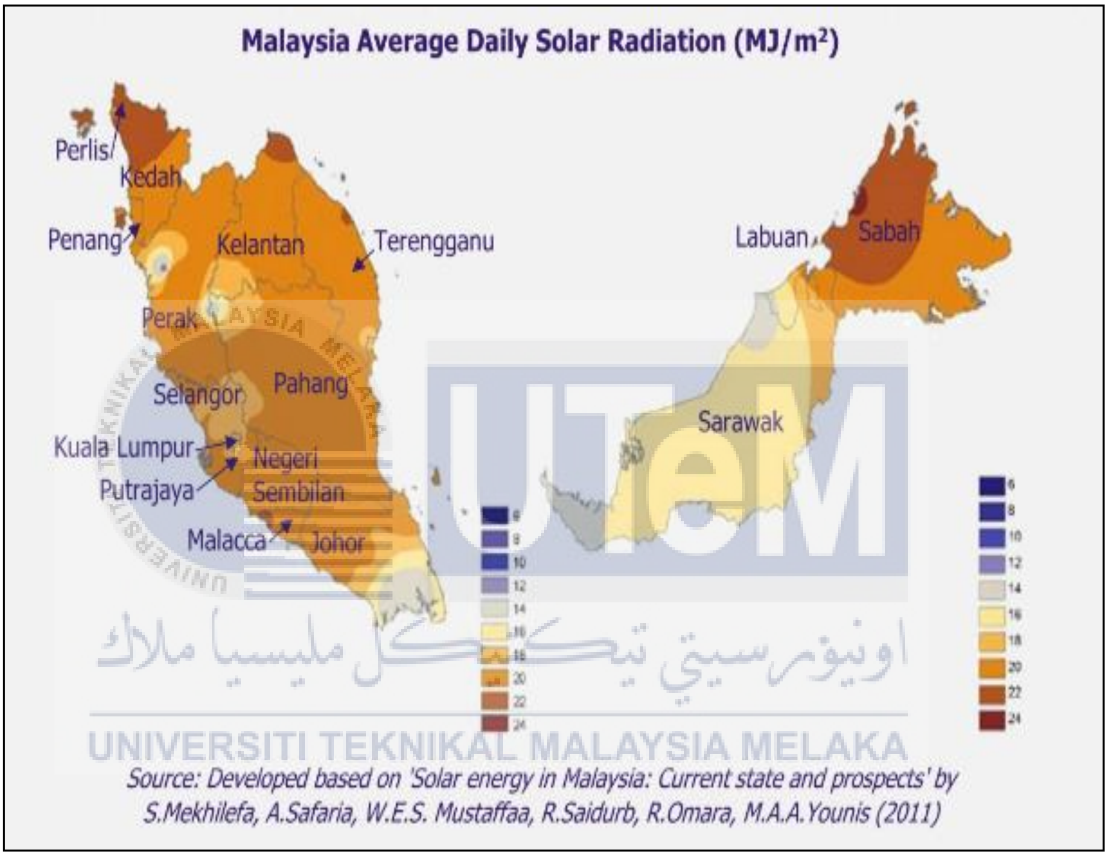
```
#include <Servo.h> // include Servo library

// 180 horizontal MAX

Servo horizontal; // horizontal servo

int servoh = 180;   // 90;     // stand horizontal servo


int servohLimitHigh = 180;

int servohLimitLow = 65;


// 65 degrees MAX

Servo vertical;   // vertical servo

int servov = 45;    //   90;     // stand vertical servo

int servovLimitHigh = 80;

int servovLimitLow = 15;


// LDR pin connections

//  name  = analogpin;

int ldrlt = 2; //LDR top left - BOTTOM LEFT    <--- BDG

int ldrrt = 3; //LDR top rigt - BOTTOM RIGHT

int ldrld = 0; //LDR down left - TOP LEFT

int ldrrd = 1; //ldr down rigt - TOP RIGHT


void setup()
```

```
{
  Serial.begin(9600);
// servo connections
// name.attacht(pin);
  horizontal.attach(9);
  vertical.attach(10);
  horizontal.write(180);
  vertical.write(45);
  delay(3000);
}

void loop()
{
  int lt = analogRead(ldrlt); // top left
  int rt = analogRead(ldrrt); // top right
  int ld = analogRead(ldrld); // down left
  int rd = analogRead(ldrrd); // down rigt

  // int dtime = analogRead(4)/20;
  // int tol = analogRead(5)/4;
  int dtime = 10;
  int tol = 50;
    int avt = (lt + rt) / 2; // average value top
  int avd = (ld + rd) / 2; // average value down
  int avl = (lt + ld) / 2; // average value left
  int avr = (rt + rd) / 2; // average value right
```

```
int dvert = avt - avd; // check the diffirence of up and down
int dhoriz = avl - avr;// check the diffirence og left and right

if (-1*tol > dvert || dvert > tol) // check if the diffirence is in the tolerance else
change vertical angle
{
if (avt > avd)
{
  servov = ++servov;
   if (servov > servovLimitHigh)
   {
    servov = servovLimitHigh;
   }
}
else if (avt < avd)
{
  servov= --servov;
  if (servov < servovLimitLow)
{
  servov = servovLimitLow;
}
}
vertical.write(servov);
}
```

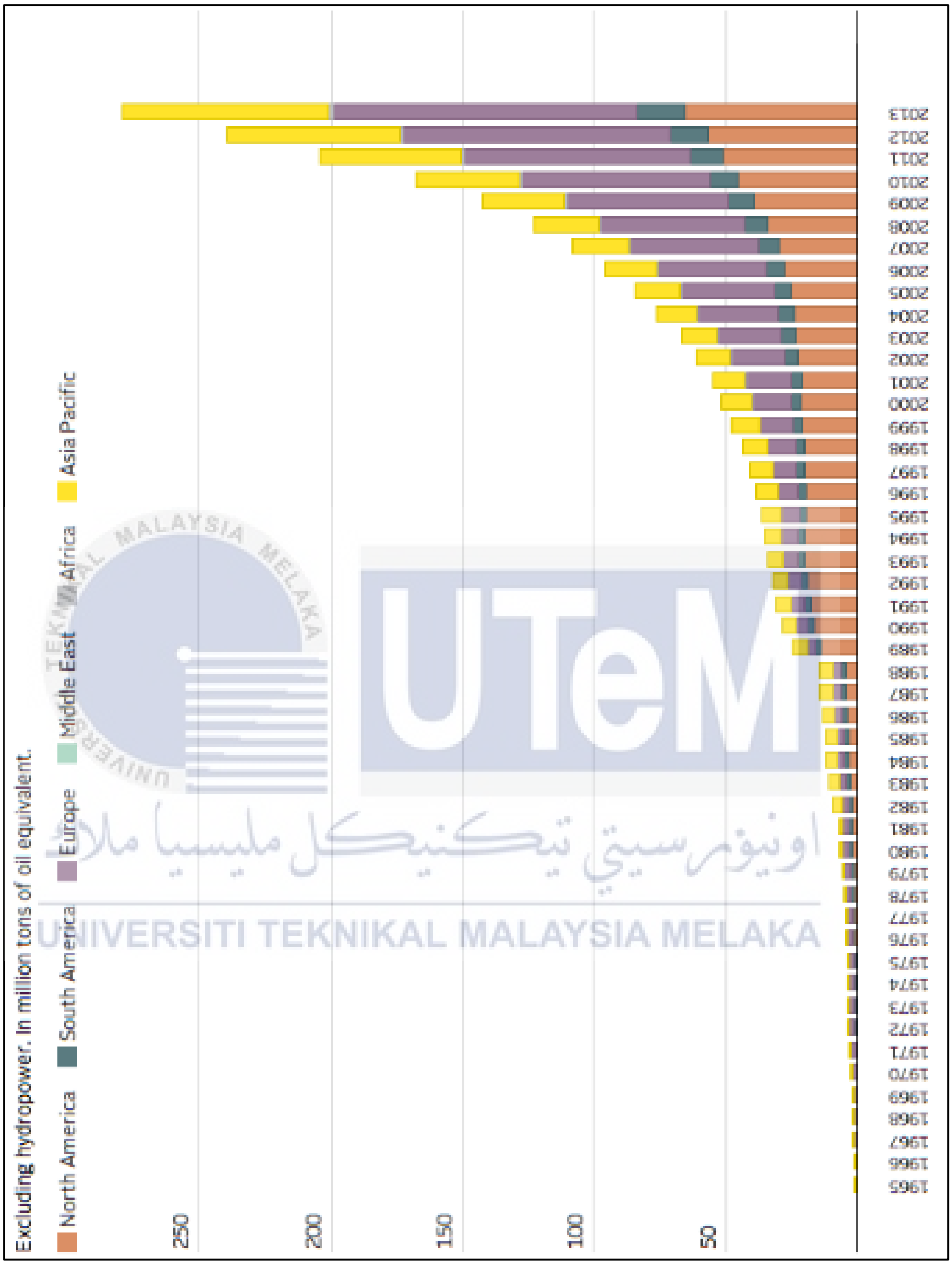
```
 if (-1*tol > dhoriz || dhoriz > tol) // check if the diffirence is in the tolerance else
change horizontal angle
 {
 if (avl > avr)
 {
   servoh = --servoh;
   if (servoh < servohLimitLow)
   {
   servoh = servohLimitLow;
   }
 }
 else if (avl < avr)
 {
   servoh = ++servoh;
    if (servoh > servohLimitHigh)
    {
    servoh = servohLimitHigh;
    }
 }
 else if (avl = avr)
 {
   // nothing
 }
 horizontal.write(servoh);
 }
  delay(dtime);
```

APPENDIX C



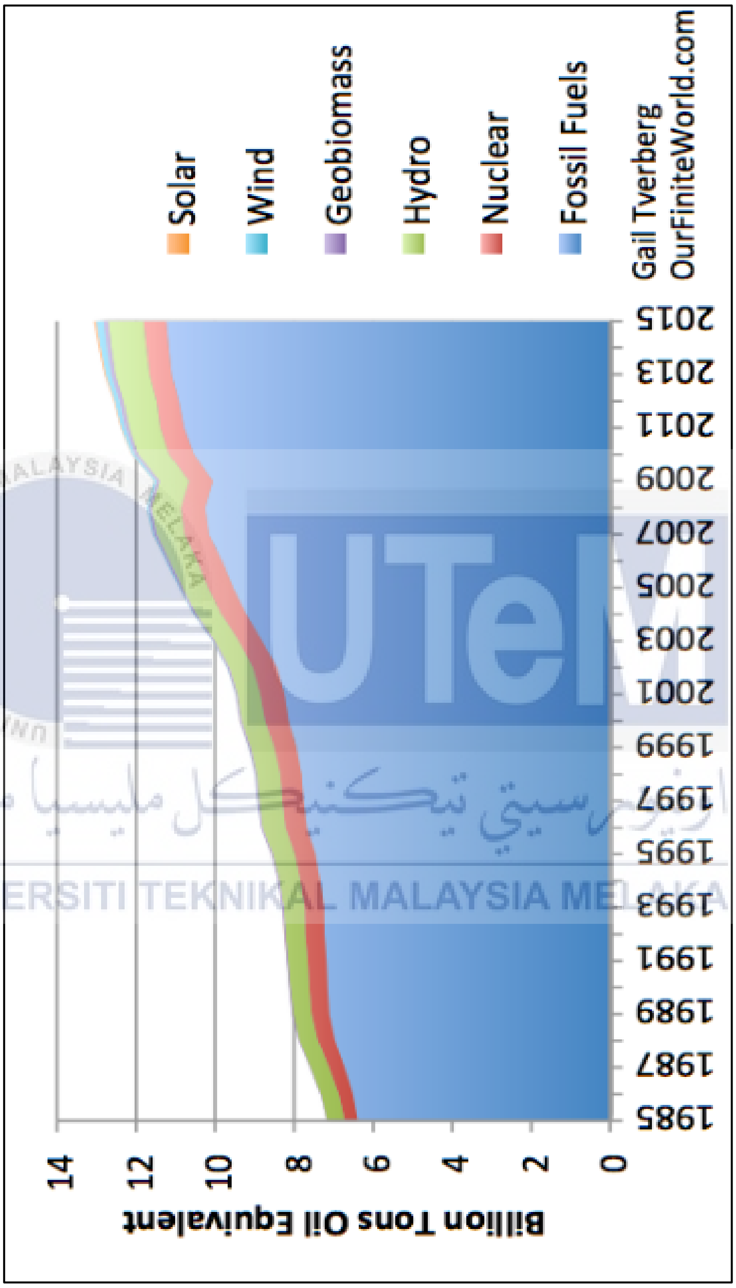
Statistic of Average Solar Radiation in Malaysia

APPENDIX D



Statistic Renewable Energy

APPENDIX E



World Energy Consumption

APPENDIX F

YIELD COMPARISON BETWEEN A FIXED AND A SOLAR TRACKING INSTALLATION						
Year 2012	Daily Yield Fixed		Daily Yield Tracked			
	2.8 kW Fixed System		10 kW Tracked System		Surplus	Surplus
Month	kWh	kWh/kWp/day (A)	kWh	kWh/kWp/day (B)	kWh (B - A)	%
March	367.0	4.2	2164.0	7.0	2.8	67%
April	369.0	4.4	1603.0	5.3	0.9	20%
May	352.0	4.1	1504.0	4.9	0.8	20%
June	307.0	3.7	1267.0	4.2	0.5	14%
July	340.0	3.9	1476.0	4.8	0.9	23%
August	340.0	3.9	1549.0	5.0	1.1	28%
September	366.0	4.4	1855.0	6.2	1.8	41%
	348.7	4.1	1631.1	5.3	1.2	30%

Usage of Fixed and Solar Tracking Installation