“I hereby declare that I have read through this report entitle ‘*Effect of Cloud On Solar Photovoltaic Module Output*’ and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”.

Signature : ……………………………………………

Supervisor’s Name : Prof. Madya Dr. Gan Chin Kim

Date : ……………………………………………

EFFECT OF CLOUD ON SOLAR PHOTOVOLTAIC MODULE OUTPUT

TAUFIK HIDAYAT BIN DARMAWAN

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

"I declare that this report entitle '*Effect of Cloud on Solar Photovoltaic Module Output*' is the result of my own research 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	:………………………………..
Student's Name	: Taufik Hidayat Bin Darmawan
Date	:………………………………..

To my beloved mother and father

ACKNOWLEDGEMENT

First of all, Alhamdulillah and thank to Allah on His Blessing that give the opportunity to complete this project. A very high gratitude I'm expressing to my dedicated supervisor, Prof. Madya Dr. Gan Chin Kim for his valueable guidance, enthusiasm and motivation given throughout the progress of this project. Besides that, I would also like to thank to all UTeM lecturers and staff especially En. Yusri who had help me in doing my final year project. Not forgotten to my colleagues for their help and support and also who had given me the advice, courage and support in completing this report. Aside from UTeM, I would like to thank to my parents for always being my side to support me all the times and for giving me the courage and strength that are necessary to complete this final year project.

ABSTRACT

Photovoltaic solar system is the technology that converts energy from sunlight into electrical energy. Generally, it consist several components including solar panel to absorb and convert the irradiance from sun light into electricity. The availability of the irradiance also depends on the weather condition that brings much variation and uncertainty. The irradiance at top of atmosphere was 1,367 W/m^2 and the radiation can easily absorbed, reflected and deflected by the cloud type. In other word, the solar irradiation will decrease because of the blocking and movement of the cloud. From that, this project had to emulate the cloud movement by replacing the cloud with tinted film. The percentage of the tinted film which is 50%, 65%, 80% and 95% to emulate the cloud that brings different effect on output PV module. The different output can be seen on the measurement of the solar such as voltage and current. Furthermore, to emulate the cloud, the panel had to create to hold the tinted film and make the panel moving slowly. The moving panel had to move with suitable gear so that it can emulate the cloud moving. From that, the required parameter can be taken with suitable equipment.

ABSTRAK

Solar sistem photovoltaic adalah teknologi yang menukarkan tenaga daripada matahari kepada tenaga elektrik. Secara umunya, ianya merangkumi beberapa komponen termasuk solar panel yang menyerap tenaga daripada matahari dan menukarkan sinaran cahaya matahari tersebut kepada tenaga elektrik. Ketersediaan sinaran matahari adalah bergantung kepada keadaan cuaca yang pastinya sentiasa berubah-berubah dan tidak dapat diramalkan. Radiasi matahari yang tertinggi di atas atmosfera adalah 1,367 W/m^2 dan radiasi tersebut amat mudah diserap, dipantulkan and dibias oleh beberapa jenis awan. Dalam erti kata lain, radiasi solar akan berkurang kerana faktor yang disebakan oleh halangan dan pergerakan awan tersebut. Daripada itu, projek ini akan mensimulasikan pergerakan awan dengan menggantikannya dengan penapis cahaya. Peratusan penapis cahaya iaitu 50%, 65%, 80% dan 95% yang bertindak sebagai awan yang memberi perubahan terhadap keluaran solar modul. Perbezaan keluaran daripada solar modul dapat dilihat dengan mengukur voltan dan arus. Tambahan lagi, untuk mensimulasikan penapis cahaya sebagai awan, sekeping panel lutsinar akan digunakan untuk memegang filem gelap tersebut dan akan digerakkan secara perlahan diatas solar panel. Penggerak panel penapis cahaya akan digerakkan menggunakan alat yang sesuai seperti roda. Seterusnya, parameter yang diperlukan akan diukur menggunakan alat pengukuran yang bersesuaian seperti solar meter dan clamp meter.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Overview

Solar energy was the one of unlimited source of renewable energy in Malaysia that located South East Asia. With the increasing of energy demand in our country nowadays, the development of solar system significantly been increase. Comparing to the other source of energy such as fossil fuel that non-renewable energy, those energy will run out of source and solar system might be the best way to back up the demand of energy requirement. Moreover, solar system has the advantage of being friendly environment and do not pollute the surrounding area. From that, the solar irradiance being the main of input in term of electricity production. A photovoltaic systems basically depends on the solar irradiance level to operate.

1.2 Motivation

The main purpose of this project was to analyse the effect of cloud on solar photovoltaic module output. To verify the effectiveness of the proposed method, comparative studies are conducted in one system with encouraging result. A combined of four different tinted layer has been used to predict or represent the effect of passing clouds on a photovoltaic (PV) systems. The PV panel relies on the sunlight irradiance which may change naturally over the time and the weather conditions. Using the irradiance as input signal, the networks model the effects of four tinted movement on the PV systems. Generally, there are tens types of cloud patterns severely affect the PV output when they shadow on the PV arrays. Each pattern allows a certain percentage of the irradiance to reach the earth's surface during a specific period of time. At the input, the combined neutral network receives the irradiance randomized by cloud movement. At the output, the same network generates simultaneously current and voltage.

1.3 Problem Statement

Generally, the irradiance totally depending form the weather condition which is often bring much of variations and uncertainty. Solar irradiance is very much affected by changes in weather. A warm, sunny day produces large solar irradiance values, while cold, cloudy days limit the available solar irradiance. Hence, clouds have a large impact on the solar irradiance received by a solar panel array. In other to understand the effect of cloud on PV module, the cloud had been replaced with tinted film which is almost all vehicle use it to reduce the heat. Hence, the tinted film that use in this project was to reduce the solar irradiance to the solar panel. For different solar irradiance transmittance condition from the tinted film which is 50%, 65%, 80% and 95%. The irradiance of solar changes over time to time provides useful information of solar irradiance record for better comprehending how quickly PV power would drop if exposed to such solar irradiance changes.

1.4 Objectives

The objectives of this project are:

i. To study the effect of the tinted film (simulating cloud) on the photovoltaic module system
ii. To analyse the performance of the film tinted under various percentage of irradiance levels

1.5 Scope of Work

This research is focused on the effect of cloud on photovoltaic module. The solar irradiance increase and drop throughout the day by day. From that, the development of the tinted film represent as the cloud movement to measure the V_{oc} and I_{sc} by moving the film slowly on the solar panel. There are four different film which is 50%, 65%, 80% and 95% that attach on the panel by using roller. Each of the layer diffuse the irradiance to the solar panel, then generate voltage and current from solar radiation. So, the measurement was conducted by using Seaward Meter and Clamp Meter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, an overview of the information and an example of related project had been involved in the development corresponding to the project. Generally describe general information regarding to the effect of the photovoltaic (PV) module system. A great interest to utilize renewable energy such as solar development had been increased in the recent years due to demanding industry and exhaustion of fossil fuel. A solar cell basically made by a p-n junction and when exposed to the sun radiation, a direct current will produce by the solar panel. Hence, the findings from other information supports the theoretically regarding the implementation of the project.

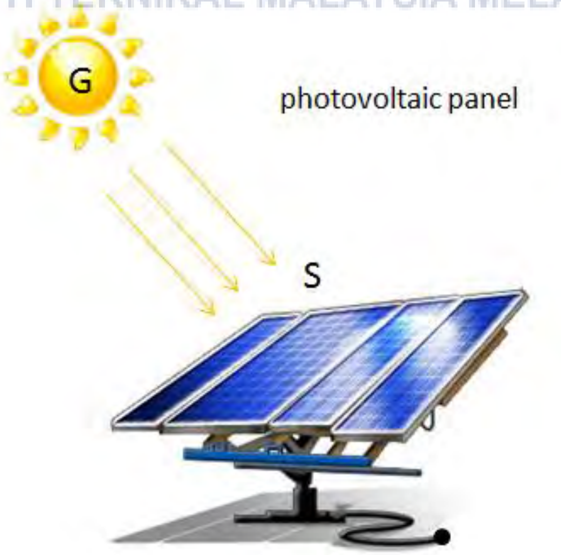


Figure 2.1: Solar radiation to the solar PV

2.2 Theory and basic Principle

Photovoltaic (PV) is the technical term for solar electric. Photo means "light" and voltaic means "electric". Besides that, solar cells are semiconductor devices that convert sunlight into direct current (DC) electricity. The materials solar panel that used in this project was mono-crystalline silicon and polycrystalline silicon.

A number of solar cells electrically connected to each other and mounted in a support structure frame is called a photovoltaic module. Basically one single cell can produces about 0.5 volt and then form modules after connected together [1]. The combination connected of modules can form a larger unit called arrays as shown in Figure 2.2 below.

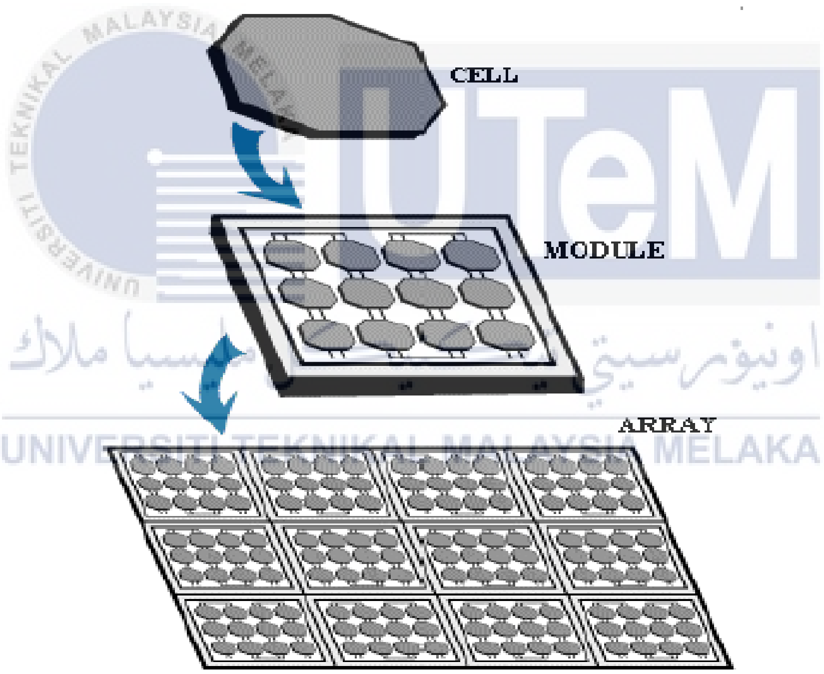


Figure 2.2: Part of PV cell, module and array

2.2.1 Solar Cell Principle

Solar cells are made of semiconductor materials such as silicon. For solar cells, when the sunlight strikes the cell, electrons are knocked loose. Then they move toward the treated front surface. An electron imbalance is created between the front and back. When two surfaces are joined by a connector, the current of electricity occurs between the negative and positives sides. Figure 2.3 below shows the electron and current flow in solar cells basically.

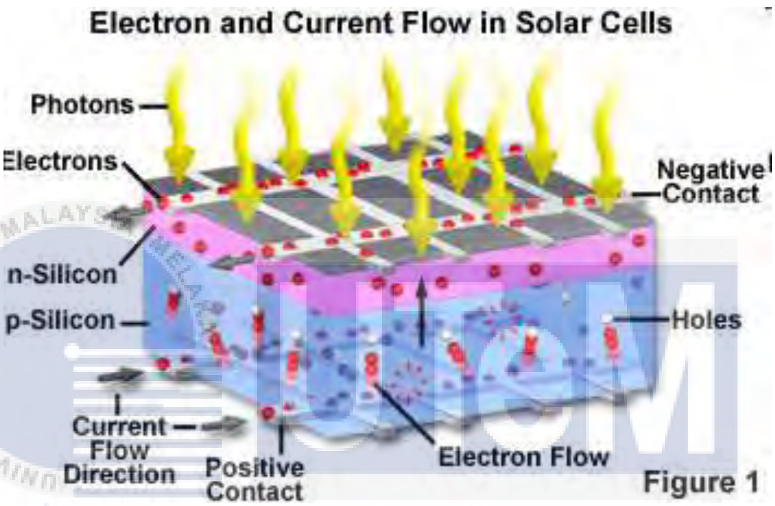


Figure 2.3: Electron and current flow in solar cells

The electron was flow in one direction and then generated electricity (DC). The input of the solar cells to generate electricity was the irradiance from the sunlight. Solar irradiance is measured in W/m^2 and is the amount of solar radiation power over a given surface area in square meters.

2.2.2 Solar Cell Structure

Solar cell are structured in layers with different functions. The working principle is the same as in semiconductors. The main part of silicon (Si) solar cell generating solar power is formed by two differently doped (n- and p-) silicon layers. A physical barrier is created between them along the p-/n- junction, with electrons and holes diffusing into regions of lower concentration. To be able to channel electrons and holes and generate electric power, metal contacts need to be printed onto the front and rear side. To reduce light reflection, a thin film of silicon nitride or titanium dioxide is coated onto the surface. Figure 2.4 below show the part of inside the solar panel which consists of P-doped silicon, P-n junction, glass, N-doped silicon, metal backing.

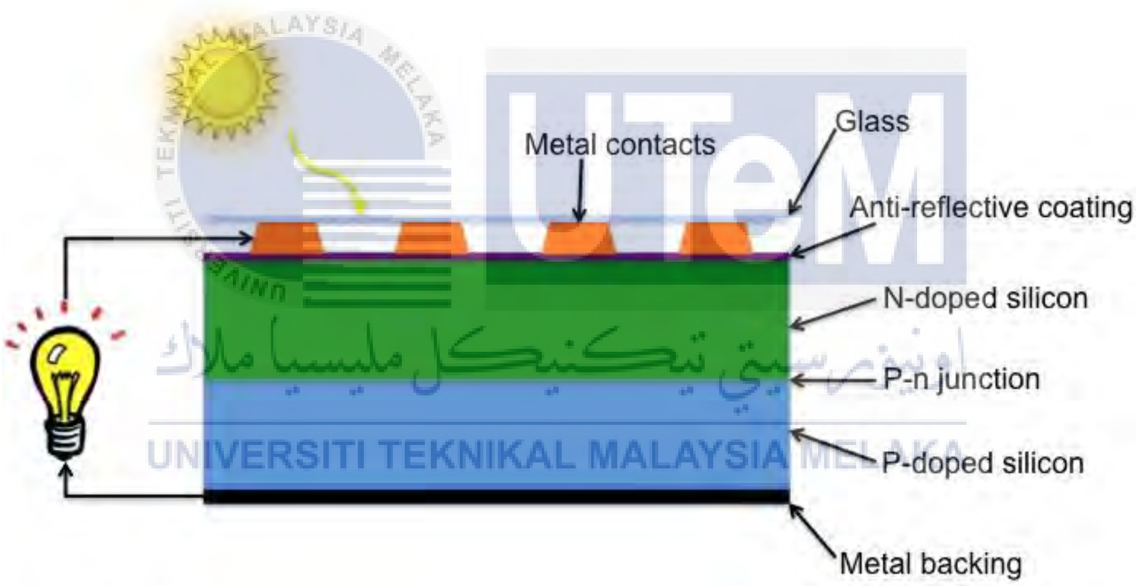


Figure 2.4: Solar cell structure

2.2.3 Solar Radiation

Solar radiation basically is the light and energy from the sun and there are many different forms. Besides that, the irradiance integrated over time is called solar irradiance and solar insolation. As shown in Figure 2.5, it show the solar radiation spectrum from at sea level to the top of the atmosphere.

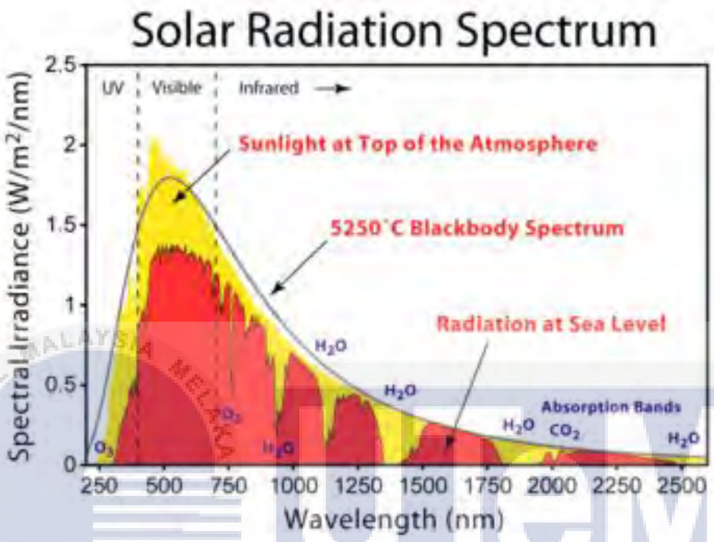


Figure 2.5: Solar radiation spectrum [17]

From Figure 2.6, it show the basic connection of solar system. The solar cells can generate more electricity during clear days with abundant sunlight. The amount of the voltage solar cells produce was depending on the clouds type and may vary by the type of solar panel. Good solar panels are better to use to receive the diffuse light that cause from the cloud.

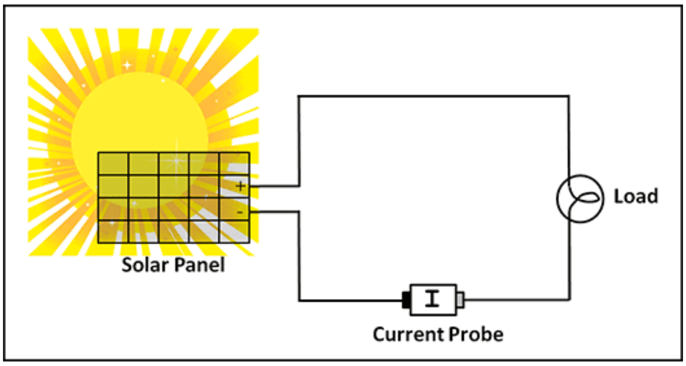


Figure 2.6: Basic connection of solar

As shown in figure 2.7, the current produce is directly dependent on the irradiance of the sunlight. In other words, during full sunlight, the solar cells will receive the maximum levels of panel capacity to form electricity. But, when the solar cells are covered, the amount of the irradiance from sunlight to the solar panel was reduced. The decreasing of the irradiance may disturb the production but the solar cells operate at about minimum capacity.

Malaysia located in the equatorial region and exposed to ample and constant sunshine generally and it is suitable for an ideal environment for solar PV power generation. About of 17 Mega Joules per square meter (MJ/m^2) average Malaysia receive the irradiance of solar per day. All around Malaysia mostly have the availability of land for the PV installation except for Kuala Lumpur where the solar PV capacity is limited to 5 GW due to the limited area and locations for solar PV installations.

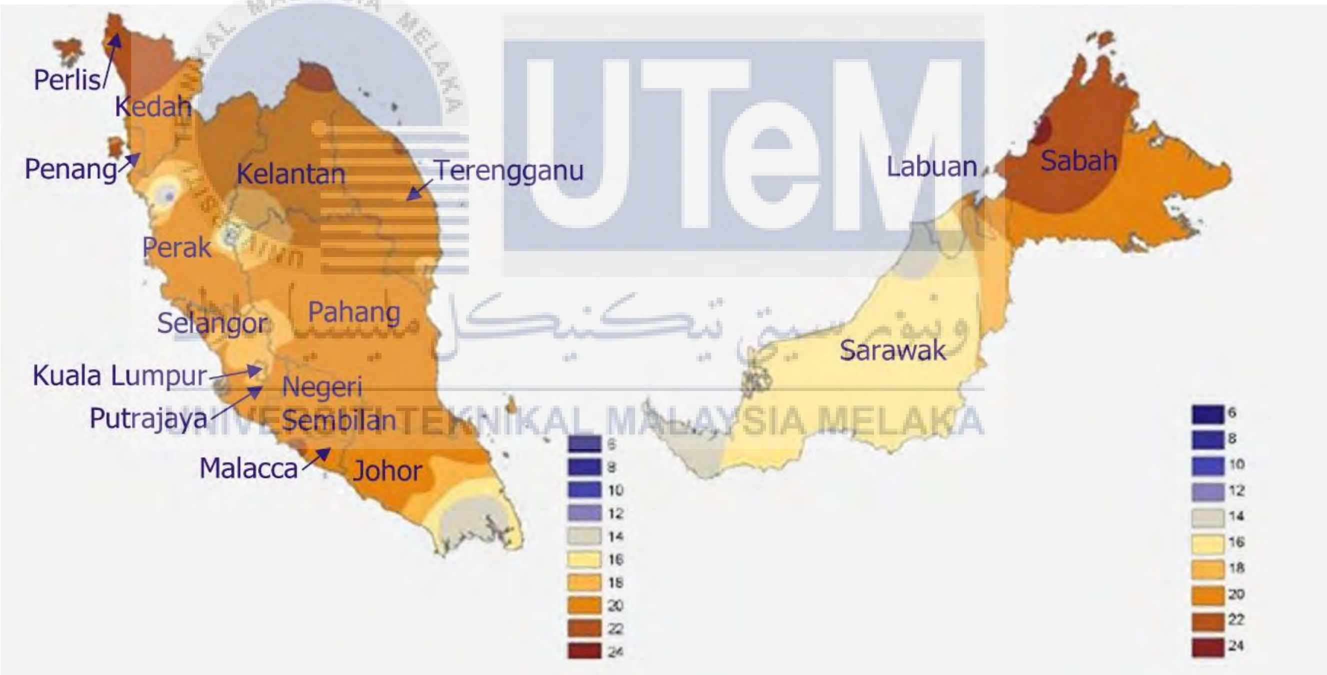


Figure 2.7: Malaysia average daily solar radiation (MJ/m^2)

Table 2.1: Solar radiation yearly for selected locations in Malaysia [16]

Cities in Malaysia	DNI [kWh/m^2]
Georgetown	1246
Kota Kinabalu	1192
Kota Bharu	1107
Senai	1045
Kuantan	1013
Durian Tunggal	973
Tawau	969
Sitiawan	949
Subang	932
Kuching	834

From Table 2.1 above, it show the solar radiation yearly for selected location in Malaysia. The Direct Solar Irradiance (DNI) show the highest value of 1246 and the lowest value is 834 for Georgetown and Kuching respectively. Meanwhile in Durian Tunggal which is location of Universiti Teknikal Malaysia Melaka show the value of DNI was 973 kWh/m^2.

2.2.4 Effect of the Colour Filter on the Solar Panel

An analysis of colour shaded to the solar panel had been done to see the effect of voltage and current as sown in Figure 2.8. Basically, the efficiency of the solar cells obtained with no colour filter due to the directly receiving irradiance. With use of colour filter, it may diffuse the irradiance to the solar cells.

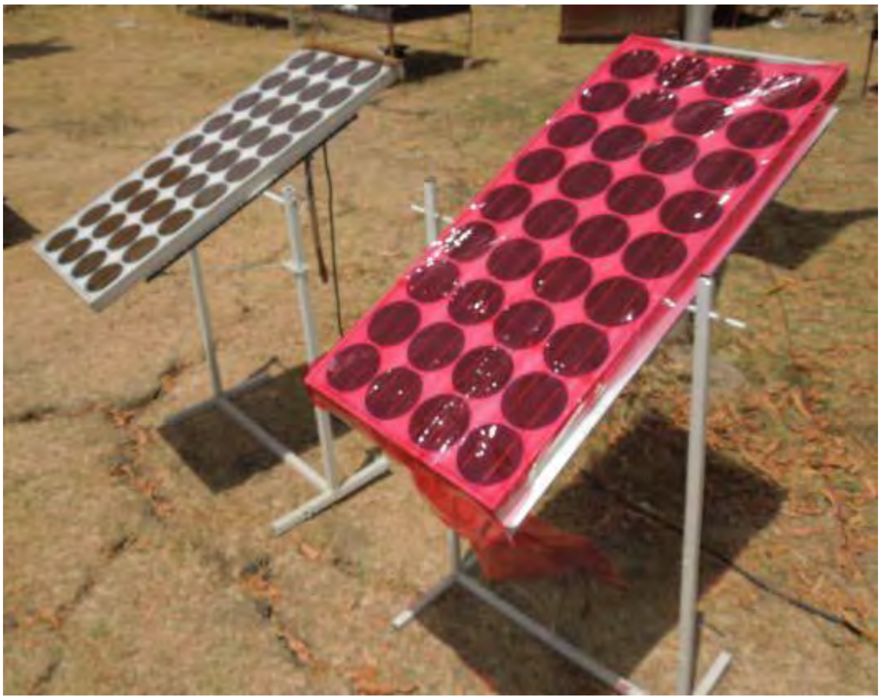


Figure 2.8: Experiment setup [19]

The results for the experiment for output power and the efficiency of the solar cells had been compared with and without colour filter in Table 2.1 below.

Table 2.2: The output with and without filter

Colour (Filter)	Current,(A)	Voltage,(V)	Power,(W)	Efficiency,(%)
No Filter	1.9	17	34.3	9.2
Violet	1.35	17	22.9	6.17
Blue	1.2	17	20.4	5.49
Green	1.5	17	25.5	6.86
Yellow	1.4	18	25.2	6.78
Orange	1.3	18	23.4	6.30
Red	1.6	18	28.8	7.75

2.2.5 Solar Irradiance Effect on PV Performance

Basically, the output power of solar cell/module directly depends on the amount of solar irradiance which is receives from the sunlight. Also it is known that the irradiance values not constant at any specific time interval. As shown in Figure 2.9, it show the changes in position of the sun with respect to earth are one of the main reasons causing the variations in the amount of incoming sunlight and its energy to the earth's surface on photovoltaic module.

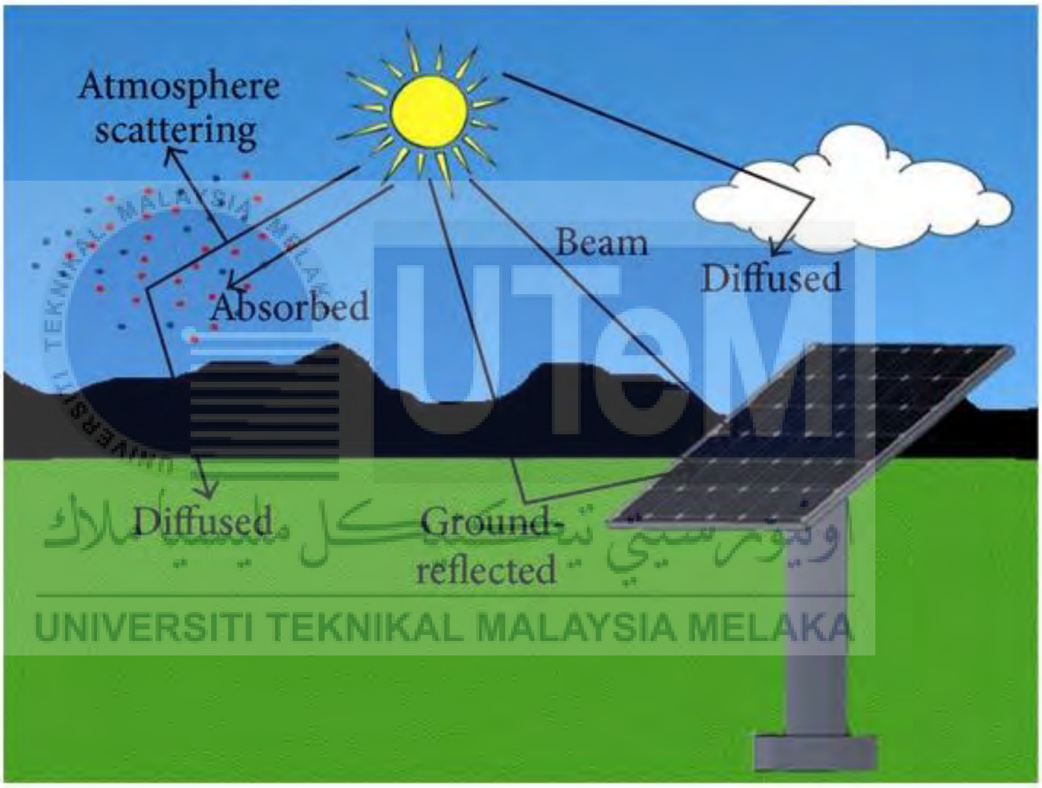


Figure 2.9: Flow of solar radiation on PV [1]

2.2.6 I-V Characteristic Curves with Variable Irradiance

It is very important to know at which solar irradiance (W/m^2) to make the measurement for the solar panel. This is because the solar radiation varies from time to time. At the same time, the tilt of solar panel also important to get the maximum output and the value in the name plate at the back of each solar panel are measured at Standard Test Conditions (STC) (i.e., V_{OC}, I_{SC}, V_{MP}, I_{MP}, °C = 25, G = 1000 W/m^2). It is able to get the standard solar irradiance (1000 W/m^2) practically by moving the solar (tilt angle) until the values in the name plate was match by using the meter device. Generally, if the value are different, it means that the solar irradiance is less or more than 1000 W/m^2. From Figure 2.10 below, it show the unstability of solar radiation varying from time to time and can give the different results from the same PV module for the voltage and current.

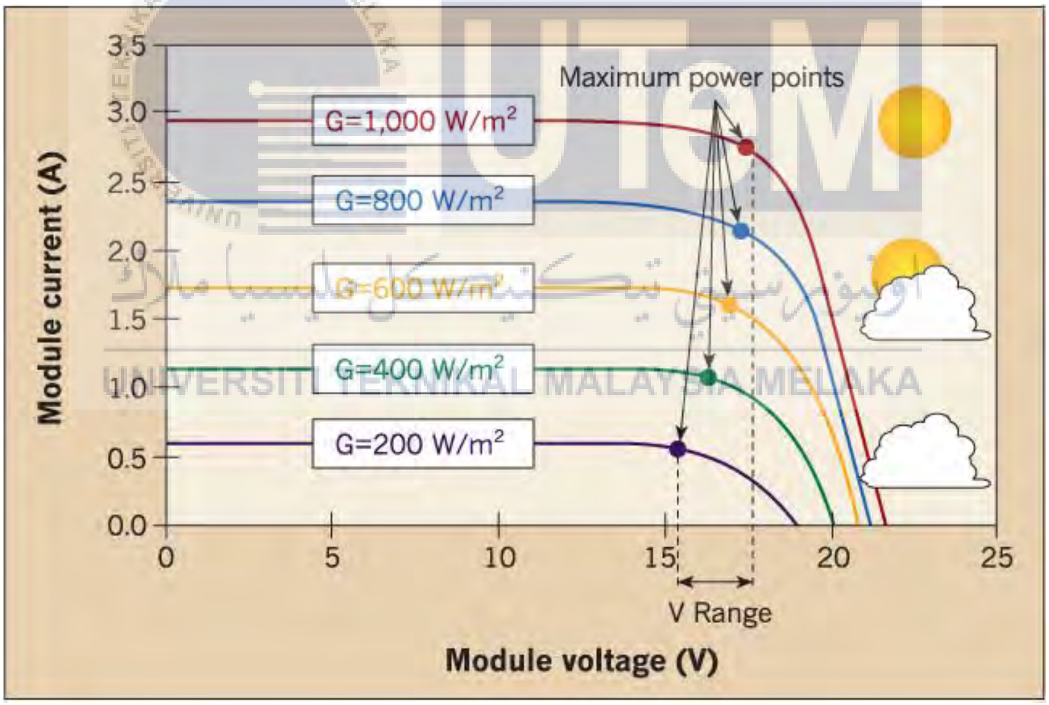


Figure 2.10: Various irradiance level

2.2.7 Tinted Film

Tinted is created when tinted film is bonded onto a piece of window glass. Generally, it was made out of clear polyster film with a very thin and even layer of tinting agents such as dyes and/or metals deposited onto the film as shown in Figure 2.11 below. Normally, without using tinted film the radiation of the sun reflects around 5% of visible light, absorb another 5%, and transmits 90% of visible light.

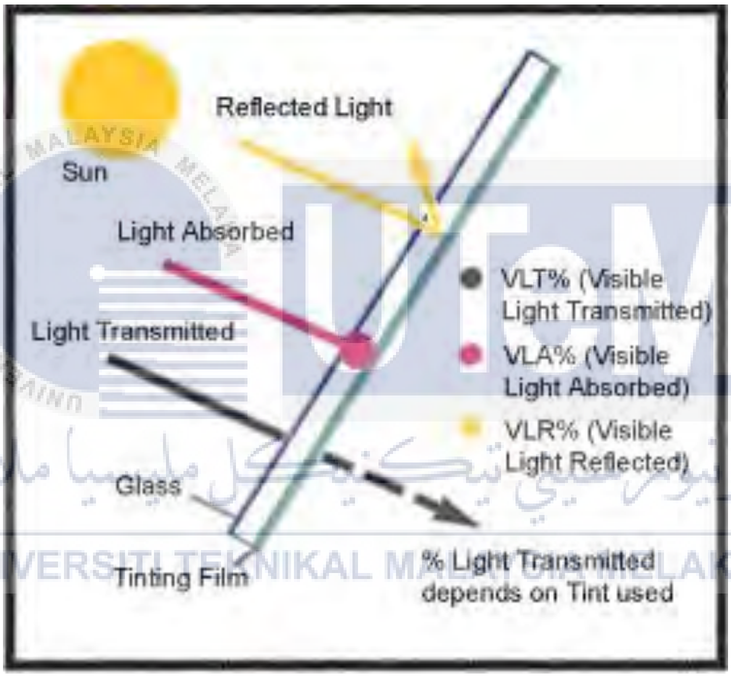


Figure 2.11: Light transmitted to tinted film

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, it will cover the techniques used in the project to make the project complete and success. The main purpose for this section was to get the information that related on the development of this project and from that, the experiment can be conduct such as measuring activities and results finding. Furthermore, in this chapter describes about the ways for the whole project that include prototype which is hardware development. Besides that, more detail discussion on the selected technique and approach use for this paper. Description of the work for this paper is explained in the form of flow chart.

3.2 Project flow chart

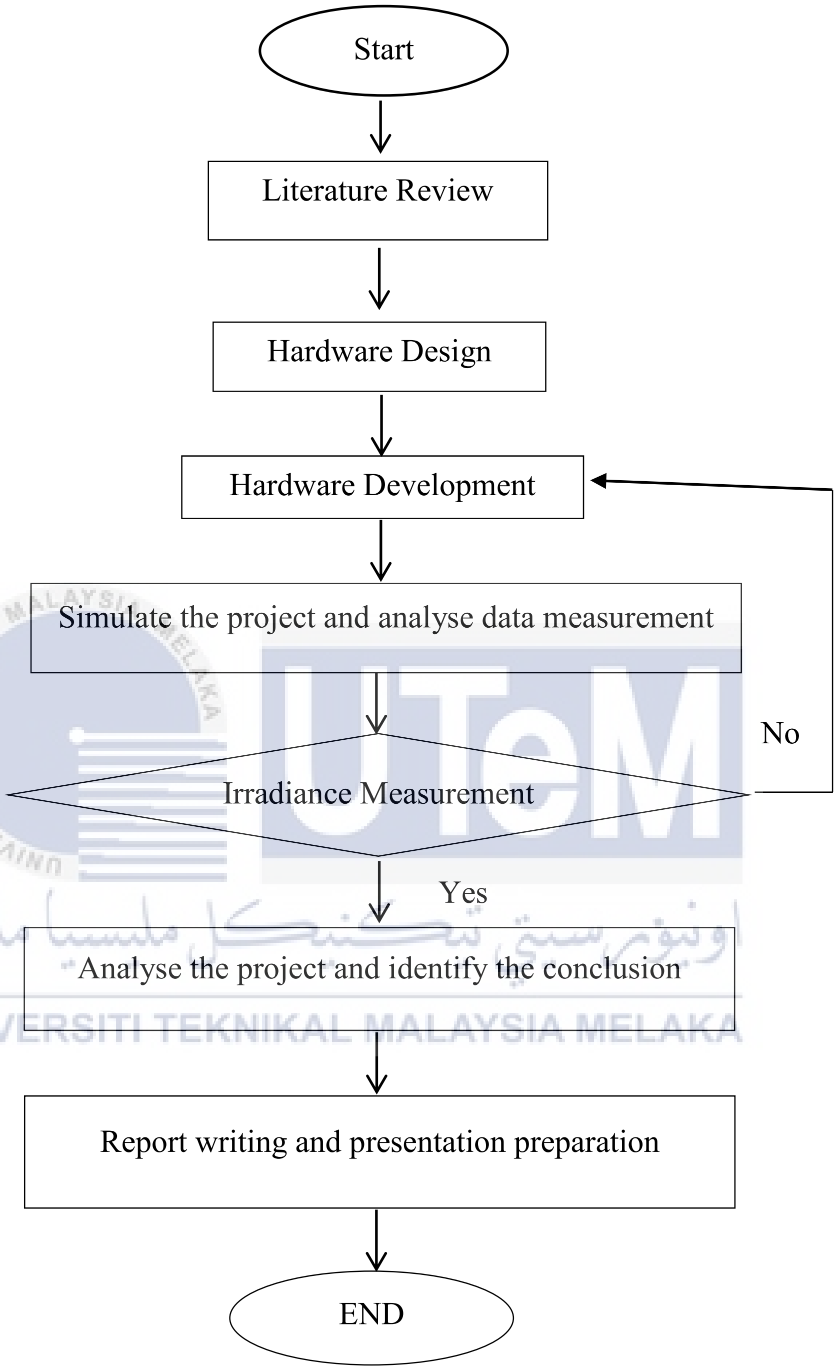


Figure 3.1: Project flow chart

3.3 Hardware Construction

As shown in Figure 3.2 below, there are four major hardware component that had been used to complete this project. Four different tinted film layer was used to simulate the cloud that diffuse the irradiance on top of solar panel. After that, the isolator of the solar panel had been switch on to produce output of V_{oc} and I_{sc}.

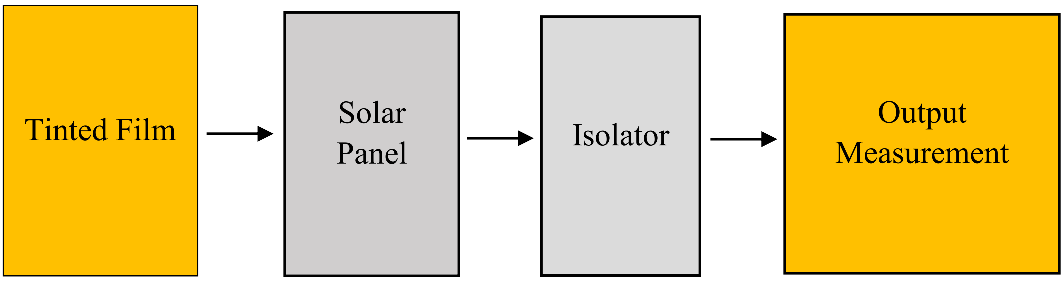


Figure 3.2: Step on construction of the hardware

The solar panel is used to generate electricity from the radiation of sunlight. As a PV cells was exposed to this sunlight, many photon are reflected either pass through it or absorbed by the solar cell. To increase the power output, the cells are combined in a weather tight package called a solar module. From one to several thousand and then wired up in serial or parallel with other that called solar array to create the desired voltage and current output required for the given project. Solar that used in this project was the solar panel model NS-130G5

Figure 3.3: Solar Panel Model NS- 130G5

Table 3.1: Characteristic of solar panel NS-F130G5 under STC

ELECTRICAL DATA	NAMEPLATES VALUES
Maximum Power, P_{max}	130 W
Tolerance of P_{max}	+7% / -2%
Open Circuit-voltage, V_{oc}	60.4 V
Short-circuit current, I_{sc}	3.41 A
Voltage at maximum power, V_{pmax}	46.1 V
Current at maximum power, I_{pmax}	2.82 A
Module efficiency, η	9.3 %
Temperature coefficient – open circuit voltage, β	-0.3% / °C
Temperature coefficient – short circuit current, α	+0.07% / °C
Temperature coefficient – power, γ	-0.24% / °C

Table 3.2: Specification I

SPECIFICATIONS (I)	
Cell	Tandem architecture of amorphous and microcrystalline silicon
Dimensions	1001 × 1402 × 7.4 mm
Weight	26 kg
Front glass	Low iron non-tempered glass
Back glass	tempered
Connection type	Cable with SMK connector

**Standard Test Condition*

A standard set of reference conditions used for the testing and rating of photovoltaic cells and modules. The standard test condition are:

- PV cell temperature at 25 degree celsius
- Irradiance in the plane of the PV cell or module at $1000W/m^2$
- Light spectrum corresponding to an atmospheric air mass of 1.5

Theoretical basis

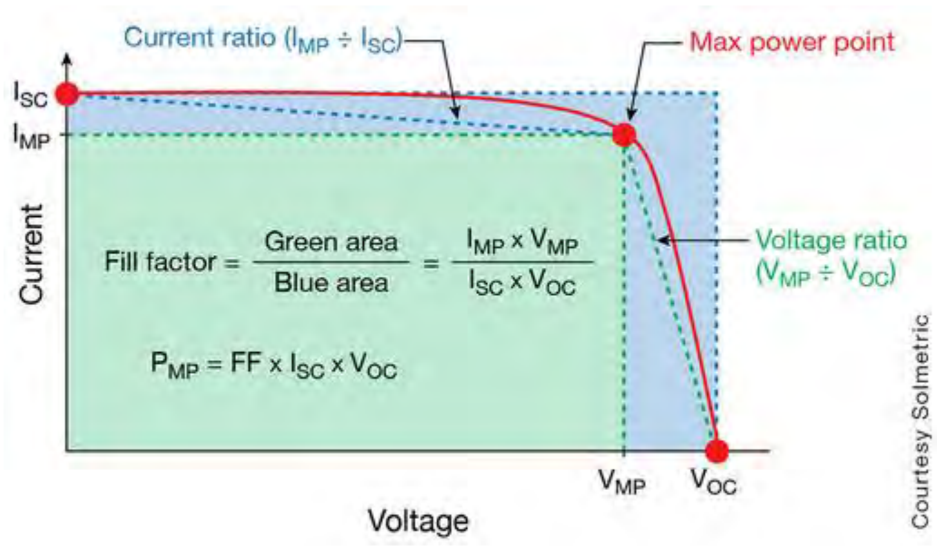


Figure 3.4: Fill factor measurement

Fill Factor, FF $= \frac{(Imp)(Vmp)}{(Isc)(Voc)}$

$= \frac{(2.82)(46.1)}{(3.41)(60.4)}$

= 0.631 or 63.1%

The output power of a PV array depends on various environmental factors such as solar irradiance. In order to calculate the amount of energy absorb by the PV cell, one has to know the value of solar irradiation G(t). Applying the open circuit condition, I = 0, to the I(V) equation is given in:

$$I = 0 = I_{sc} - I_0 (e^{Voc/Vt} - 1) \qquad [1]$$

The open circuit voltage is given by:

$$V_{oc} = V_T \, ln \, (1+\frac{Isc}{Io}) \qquad [2]$$

From equation (2), it can be seen than the value of the open circuit voltage depends, logarithmically on the Isc / I_O ratio. This means that under constant temperature the value of the open circuit voltage scales logarithmically with the short circuit which, in turn scales linearly with irradiance resulting in a logarithmically dependence of the open circuit voltage with irradiance. This is also an important result indicating that the effect of the irradiance is much larger in the short circuit current than in the open circuit voltage.

3.4 Component of hardware

There are four different layer of tinted film which is 50%, 65%, 80% and 95% that used in this project to analyse the output from solar panel as shown in Figure 3.5. The tinted film was attach on top of transparent panel that can slide on top of solar panel that represent the cloud movement.

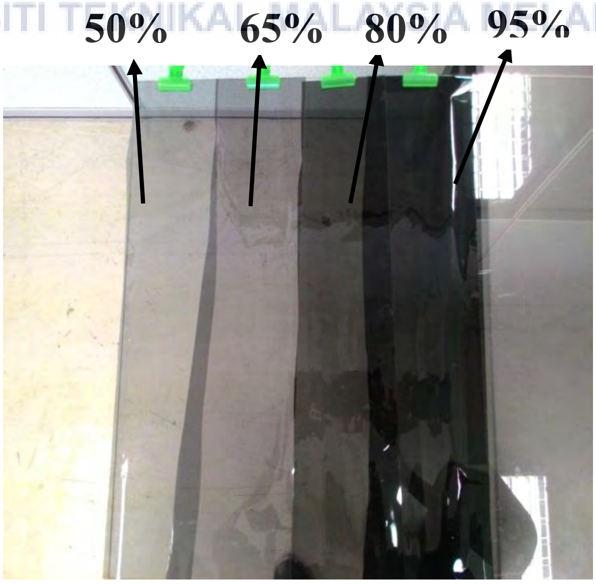


Figure 3.5: Four different percentage of tinted film

Figure 3.6: Tinted film on solar panel

By using different layer of tinted film as shown in Figure 3.5, the film was attach to the transparent panel on solar panel so that it can represent as cloud movement as shown in figure 3.6 above. From that, the changes of tinted film and irradiance needed was measured in term of voltage and current as the output. Before that, the irradiance that receive on the solar panel will through to the isolator so that the V_{oc} and I_{sc} can be measured. By using clamp meter as shown in Figure 3.7, the V_{oc} and I_{sc} of the solar panel was measured as series of filters are placed over the solar panel. The irradiance measurement was measured by seaward meter as shown in Figure 3.8 below.

Figure 3.7: AC/DC Clamp Meter (DCM 400AD)

Figure 3.8: Seaward Meter (Solar Survey 200R)

Figure 3.9: Part of isolator

3.5 Software Implementation

Besides on the construction of the hardware, this project also used software to get the output needed. The software that used on this project was the Solmetric PV Analyzer. The PVA software runs on PC and is the interface for making measurements and storing, viewing and exporting data. The main screen is shown in Figure 3.10 below. Furthermore, this software can give the output which is the I-V curve that related to solar irradiance.

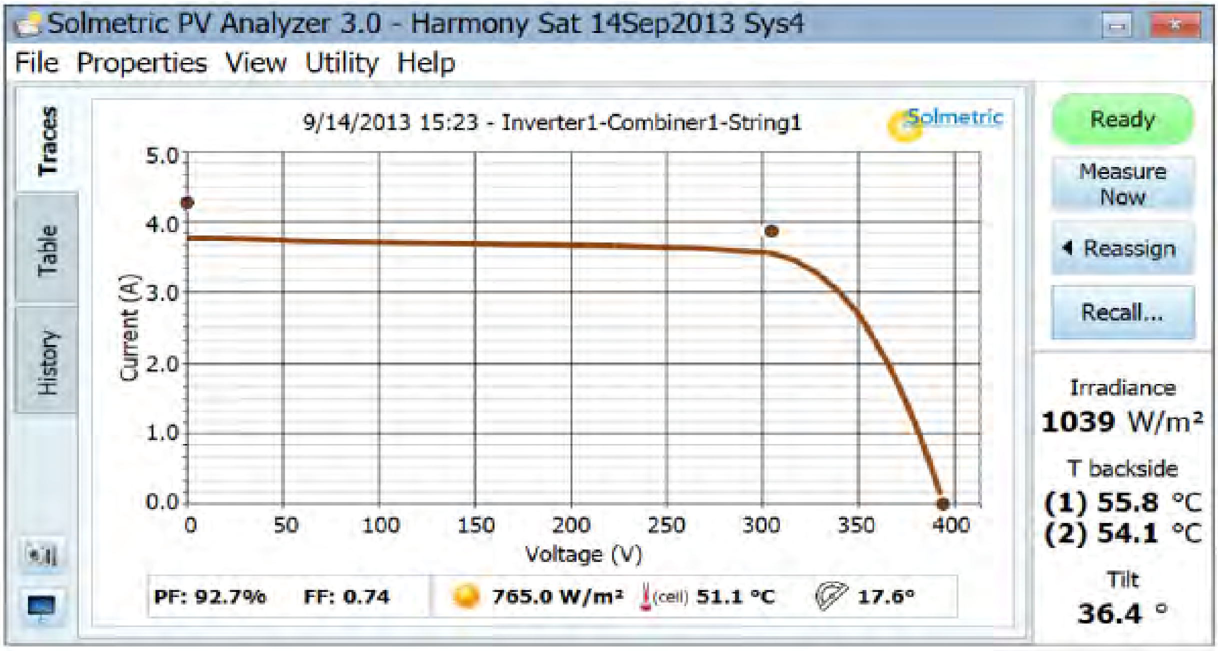


Figure 3.10: Software overview

The PVA system was designed for translating the displayed I-V curve to standard Test Conditions (STC) of 1000 W/m^2 and 25°C. As these measurements are usually performed in a 4-hour time span centered about solar noon, the measured I-V curves reflect the changes in irradiance and cell temperature that take place over the time period. Fast changes in irradiance and temperature caused by rapidly moving clouds will be difficult to correct accurately, so clearly days are still required for quality end results.

The PV Analyzer is a portable test instrument designed for commissioning and troubleshooting PV arrays. It measures the current-voltage (I-V) curves of PV modules and strings and immediately compares the results to the predictions of the built-in PV models. Measurement results are easily saved for future reference and analysis. The I-V Measurement Unit is controlled wirelessly by the portable PC via a wireless USB adapter. Wireless interfaces allow the user to move around in the immediate work area, and eliminate the trip hazards associated with hard-wired interconnections.

3.6 Data Collecting for Baseline

The data was collected at different irradiances, starting from the low irradiance needed until reach the standard conditioning test (STC) and using different layer of tinted film which is 50%, 65%, 80% and 95%. The irradiance, G (W/m^2) collected was 400 – 500, 500 – 600, 600 – 700, 800 – 900 and 900 – 1000. To collect data at different irradiance, there was the time that has low irradiance and high irradiance. For low irradiance, the time mostly on the evening and the high irradiance was on the afternoon approximately. The irradiance was measured by Seaward Meter and then the solar panel exactly faced to the sun and the measuring was collected by using two different method which is clamp meter to measure the V_{oc} and I_{sc} and the PVA used to create the IV curve.

Table 3.3: Example of data collection needed

No.	G (W/m^2)	50%	65%	80%	95%
1.	400 – 500	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}
2.	500 – 600	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}
3.	600 – 700	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}
4.	700 – 800	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}
5.	800 – 900	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}
6.	900 - 1000	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}	V_{oc}, I_{sc}

3.7 Solar Radiation Collection

Basically, the main input of this project was the irradiance from the sunlight. By measuring the variable irradiance value, the output value of V_{oc} and I_{sc} for the solar panel with the film tinted was measured as shown in chapter 4. It was important that to know at what time the irradiance needed for this project to run. Therefore, the data for the irradiance had been taken from solar laboratory to know at what time suitable to run the project as shown in Figure 3.11 until Figure 3.16 below. There are five day of irradiance that had been tracked.

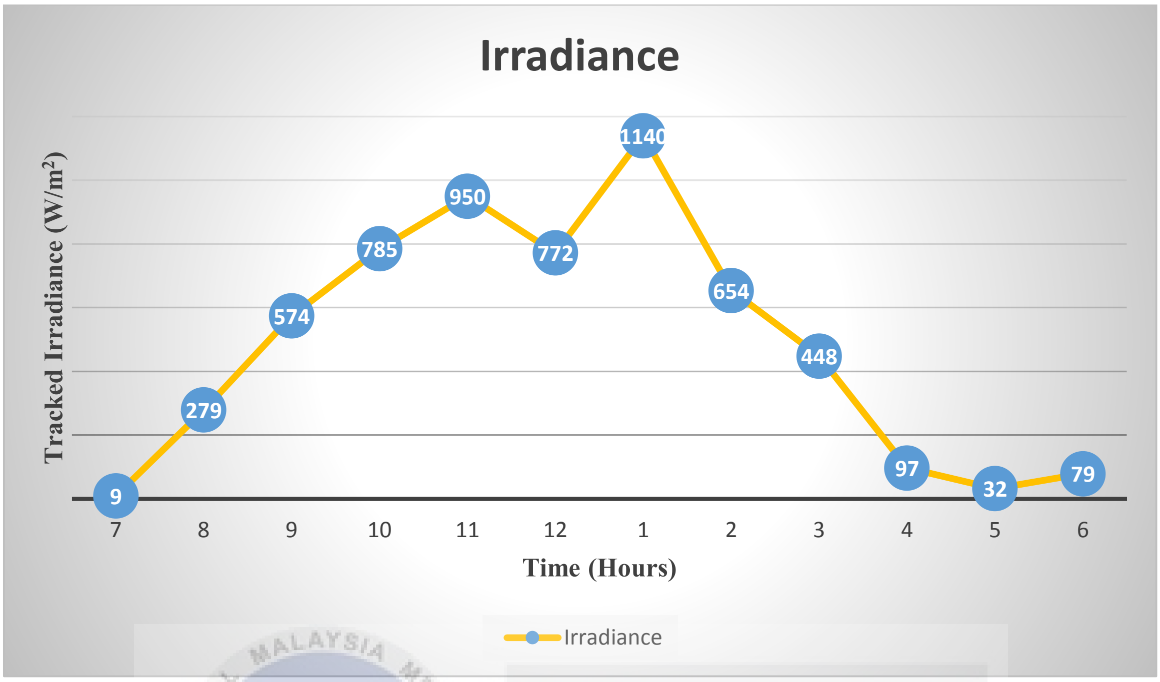


Figure 3.11: Graph solar radiation on 10/12/2015

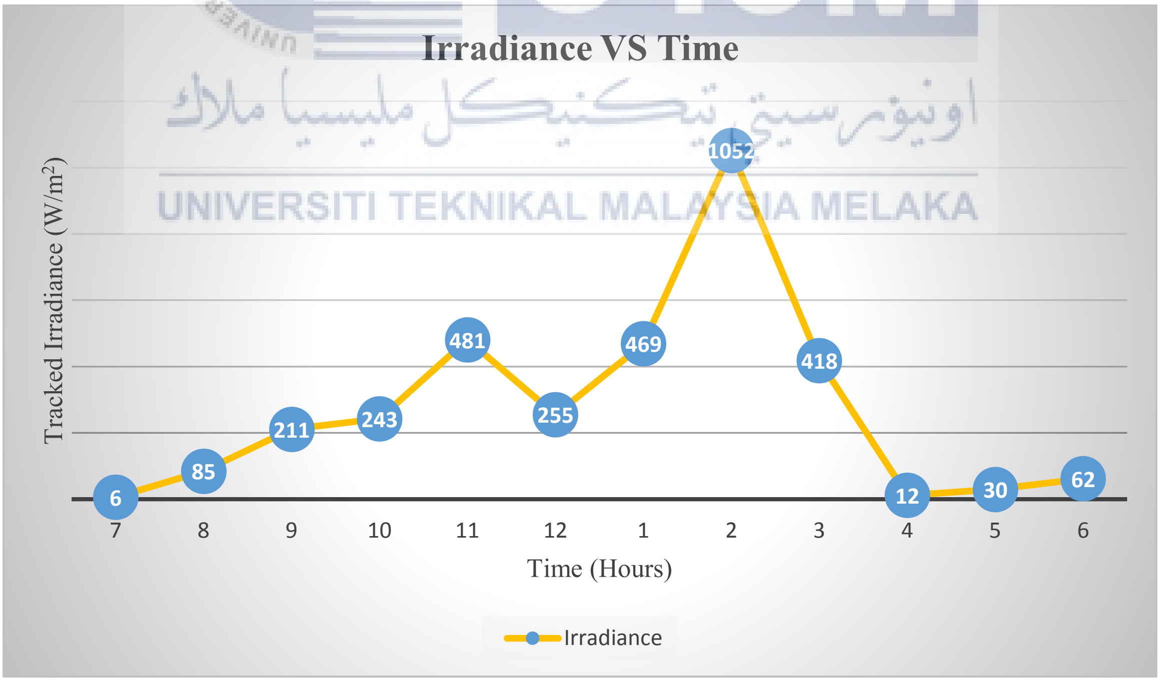


Figure 3.12: Graph solar radiation on 11/12/15

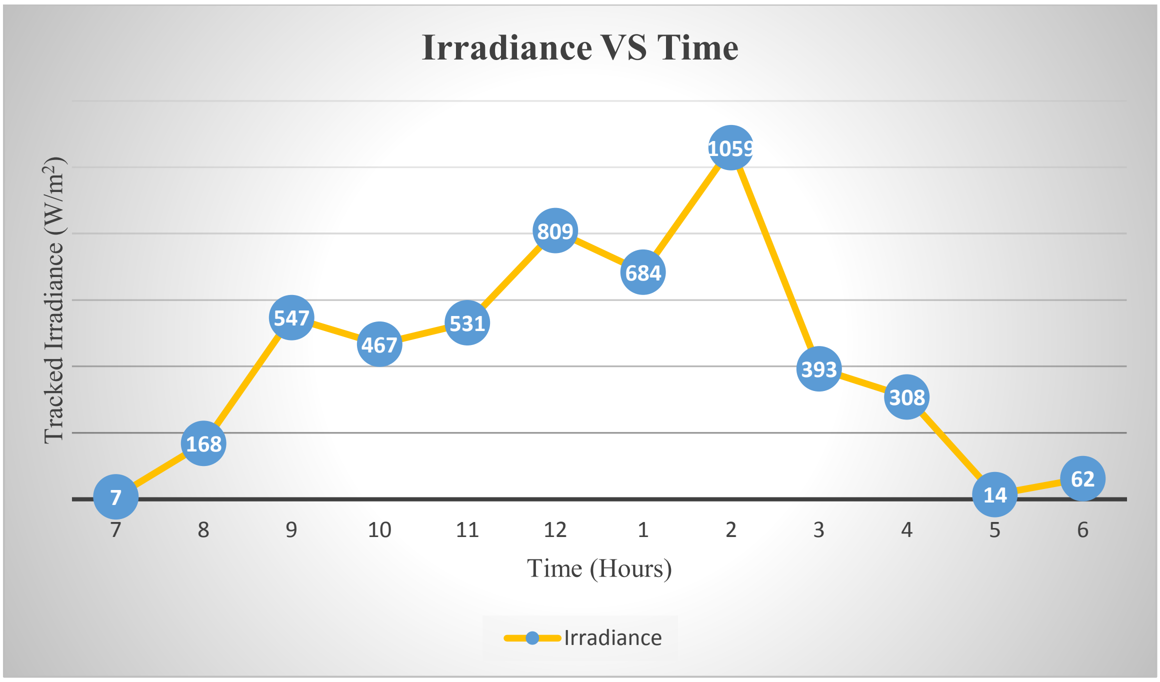


Figure 3.13: Graph solar radiation on 12/12/15

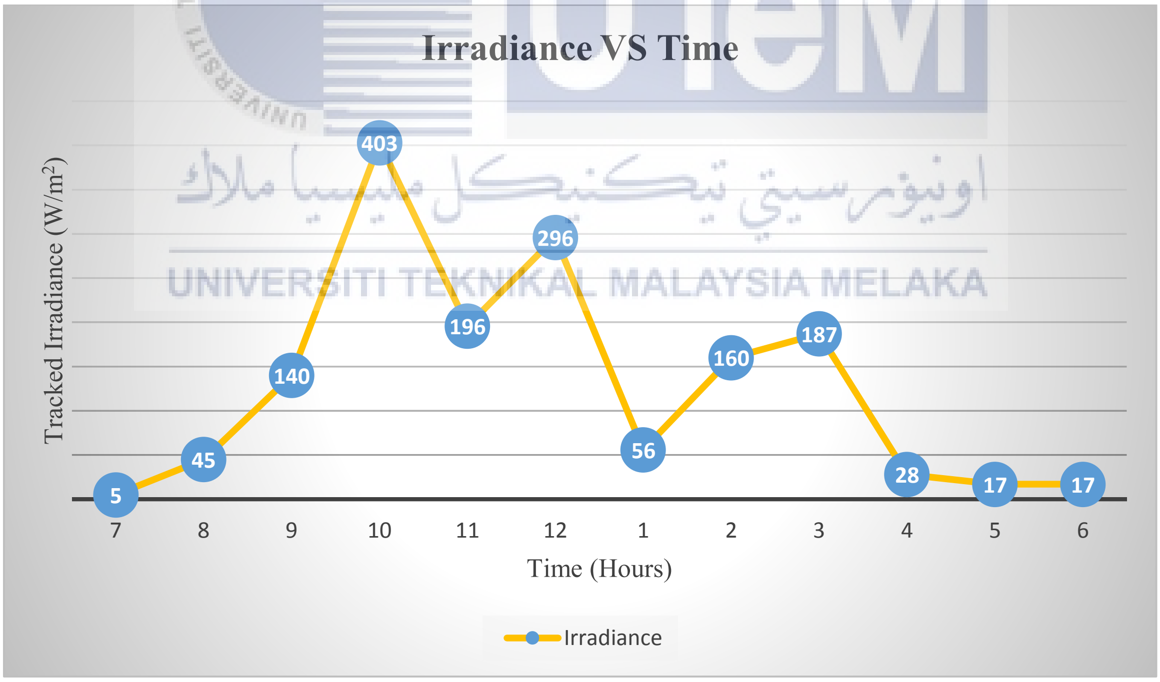


Figure 3.14: Graph solar radiation on 13/12/15

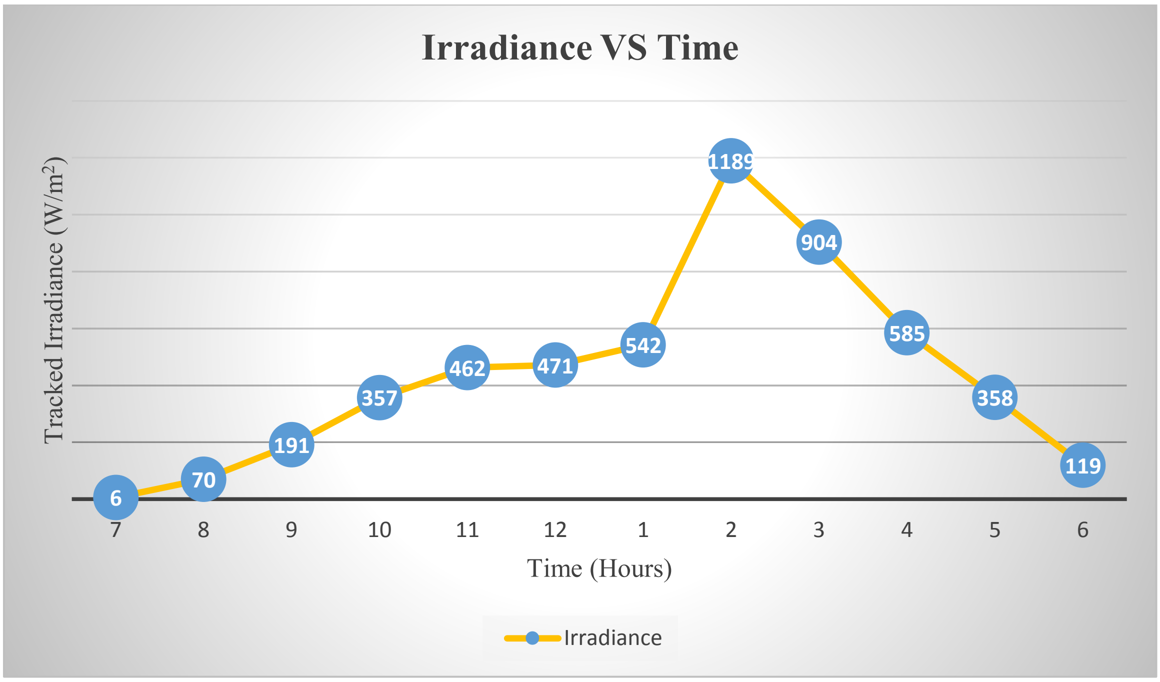


Figure 3.15: Graph solar radiation on 14/12/15

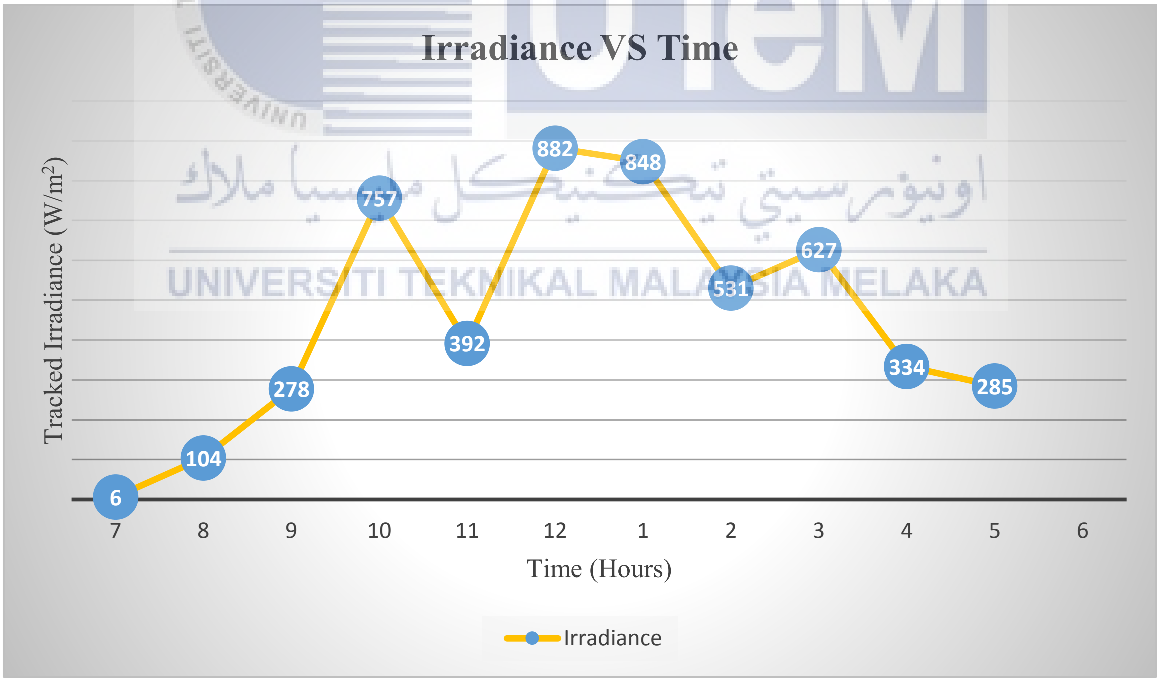


Figure 3.16: Graph solar radiation on 15/12/15

From the figure above, it show the irradiance receive at Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka during five day. The solar radiation receive sometime increase and decrease due to several factor such as cloud movement that absorb, reflected and deflected the solar irradiance.

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

This chapter will present about the result obtain. The developing of this project has been created and assembles according to the schedule. The main focus of this project was to analyse the effect of tinted film to the solar panel output. Before start the simulation, it is important to know the weather outside the laboratory because this project required the different solar irradiance. After that, the solar panel had been taken to the outside solar laboratory and with other related equipment for this project.

4.2 Measurement on solar panel output without tinted film

From Figure 4.1, the measurement had been record for the solar panel under various irradiance level. From that, the V_{oc} and I_{sc} had been measured by using Digital PV Radiometer. The measurement was carried out to find the different output measurement of without tinted film and with tinted film.

Table 4.1: Output measurement on solar panel

No.	Irradiance Level	Output measurement	
		V_{OC}, V	I_{SC}, A
1.	400 – 500	53.17	2.13
2.	500 – 600	54.29	2.26
3.	600 – 700	55.36	2.32
4.	700 – 800	55.60	2.70
5.	800 – 900	54.71	2.80
6.	900 - 1000	54.62	3.09

4.3 Measurement on solar panel output using tinted film

The performance of the solar panel is derived from I-V characteristic curves measured generally under standard test condition (T = 25°C, G = 1000 W/m^2, AM = 1.5). In this project, the following parameters that has to measure was V_{oc} and I_{sc} and different solar irradiance level as input. The voltage output of the module is measured with the module disconnected from any load. I_{sc} was the short circuit current which represents the amount of current that the solar panel supplies into a dead short.

Table 4.2: Irradiance Measurement from on tinted film

No.	Tinted Film (%)	Measured of irradiance, G(W/m^2)		Differences, %
		Before	*After*	
1.	95%	880	480	54.5
2.	80%	870	564	65
3.	65%	865	646	75
4.	50%	889	730	82

From the Table 4.2 above, it show the difference measurement of irradiance before and after below the tinted film. By using Digital PV Radiometer that measured the irradiance, the reading of irradiance under the tinted film had been record. For 95% of tinted film, the solar irradiance had been block by 45% which mean nearly half of 95% of tinted film. Due to that blocking, the solar panel that use in this project just receive 55% solar irradiance to operate. Next, about 65% or solar irradiance hit the solar panel under of 80% of tinted film. For under tinted film of 65% and 50%, the solar irradiance that can receive to the solar panel to operate was 75% and 82%.

4.3.1 95% of Tinted Film

In this part, the tinted film that use was 95% which block or diffuse the solar irradiance. It means that the solar irradiance will decrease due to the blocking from tinted film on the solar panel. The measured value under 95% of tinted film had been record as shown in table 4.3 below.

Table 4.3: Output value under 95% of tinted film

No.	G (W/m²)	Without tinted film		With tinted film	
		V_{OC}, V	I_{SC}, A	V_{OC}, V	I_{SC}, A
1.	400 - 500	53.17	2.13	49.72	0.84
2.	500 - 600	54.29	2.26	51.80	1.34
3.	600 - 700	55.36	2.32	52.11	1.46
4.	700 – 800	55.60	2.70	52.54	1.70
5.	800 – 900	54.71	2.80	52.88	1.84
6.	900 – 1000	54.62	3.09	54.10	2.19

From the table 4.3 above, it show that the output voltage does not decrease more than 49.72V. The highest voltage that had been measured was 54.10V under irradiance of 900 – 1000 W/m^2. By referring the characteristic of solar panel that had been use, the V_{oc} of solar panel was about 60.4 V. Moreover, the higher the irradiance, the higher of V_{oc} that can be measure under 95% of tinted film. The figure 4.1 below illustrate the voltage value from low irradiance to high irradiance needed.

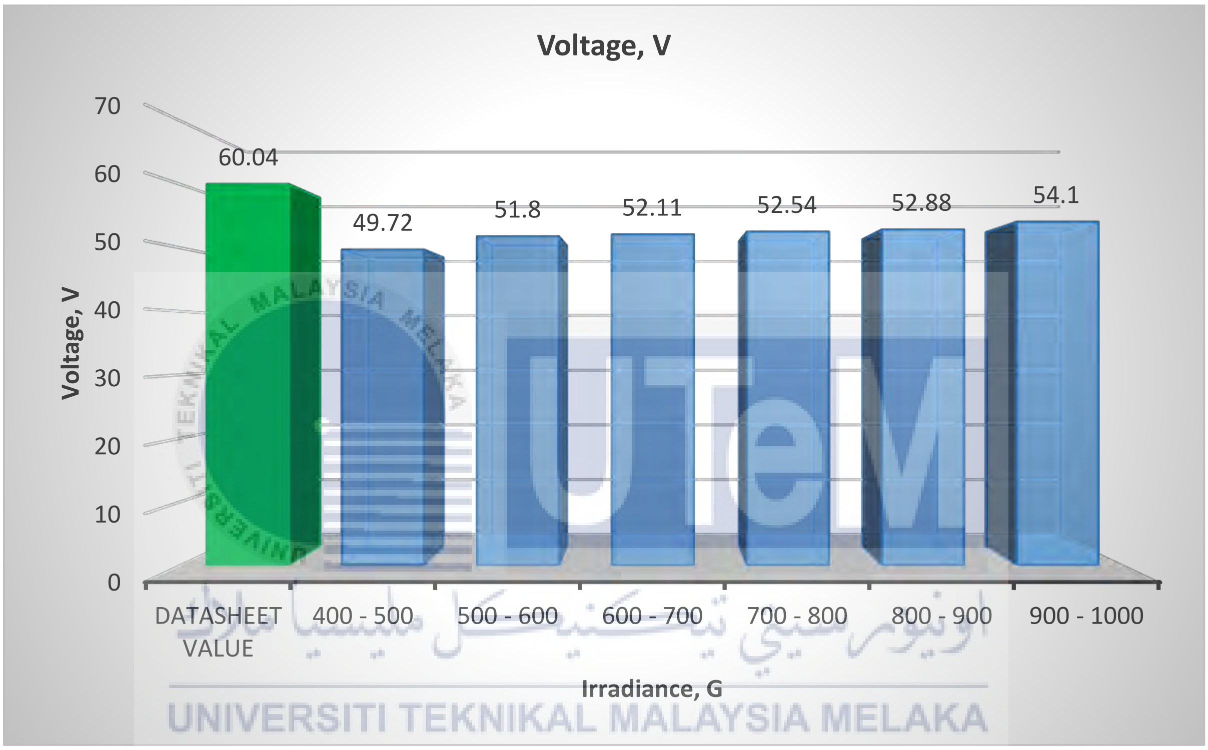


Figure 4.1: Graph voltage measurement under 95% of tinted film

The actual value I_{sc} from datasheet for solar panel is 3.41A. After completing measurement under 95% tinted film, the solar irradiance diffuse nearly more than half from the actual value which is about 75% under irradiance 400 – 500 W/m^2 from the sun as shown in figure 4.2. By increasing the irradiance measurement until 900 – 1000 W/m^2, the current had been increase about 64% from 3.41A for solar panel to receive the irradiance. Comparing the parameter of V_{oc} and I_{sc}, the current reading are more sensitive that the voltage because due to the irradiance behaviour.

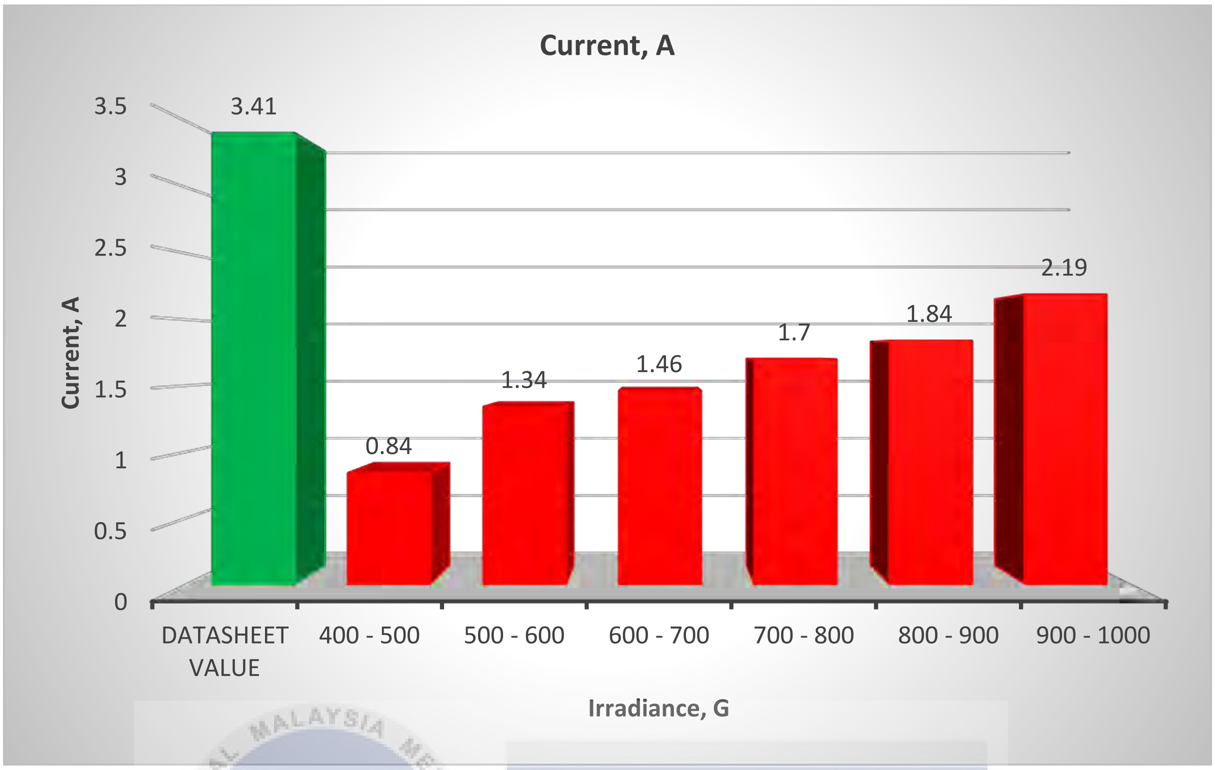


Figure 4.2: Graph current measurement under 95% of tinted film

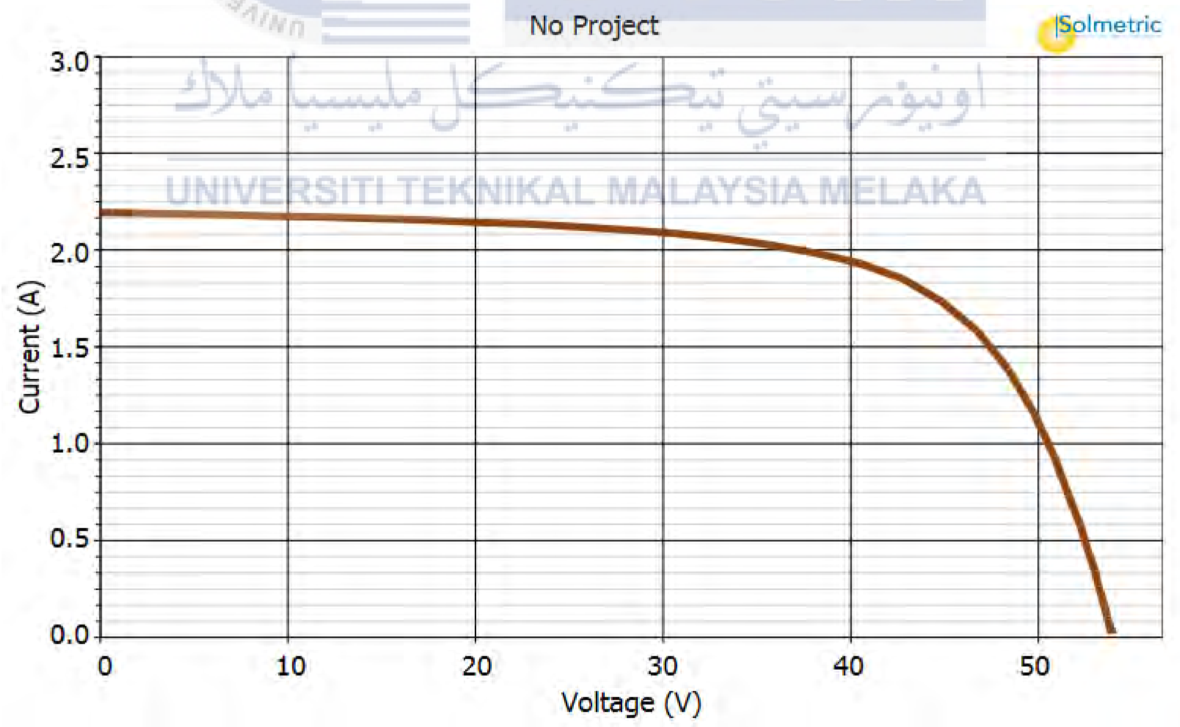


Figure 4.3: Graph I-V curve under irradiance of 900 – 1000 W/m^2

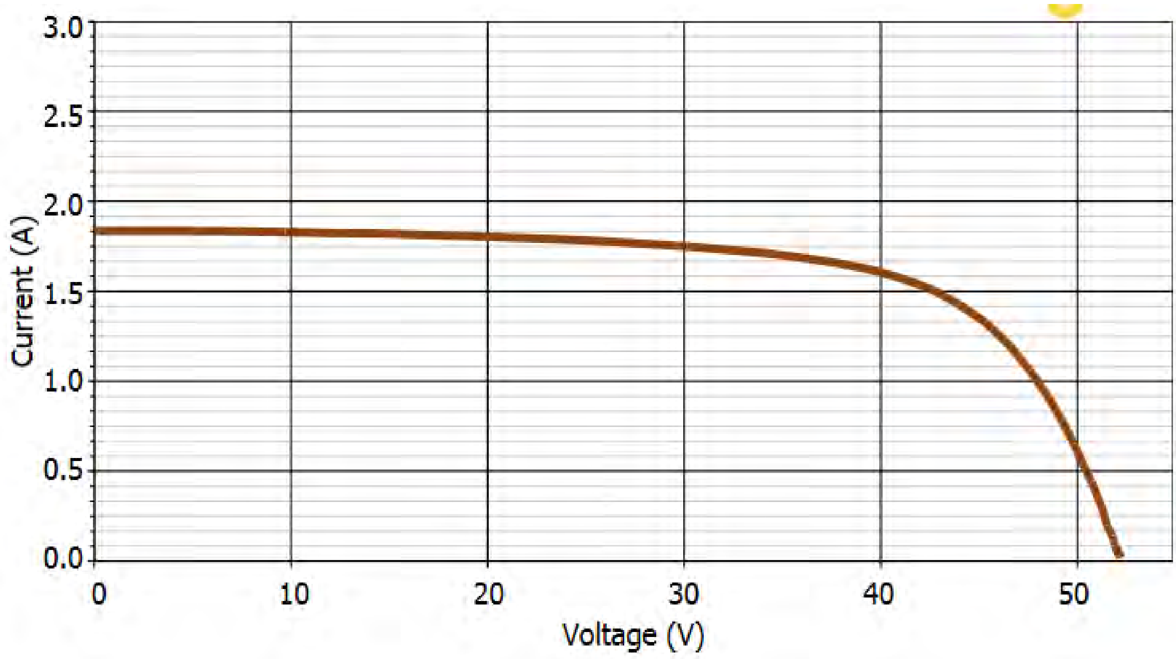


Figure 4.4: Graph I-V curve under irradiance of 800 – 900 W/m^2

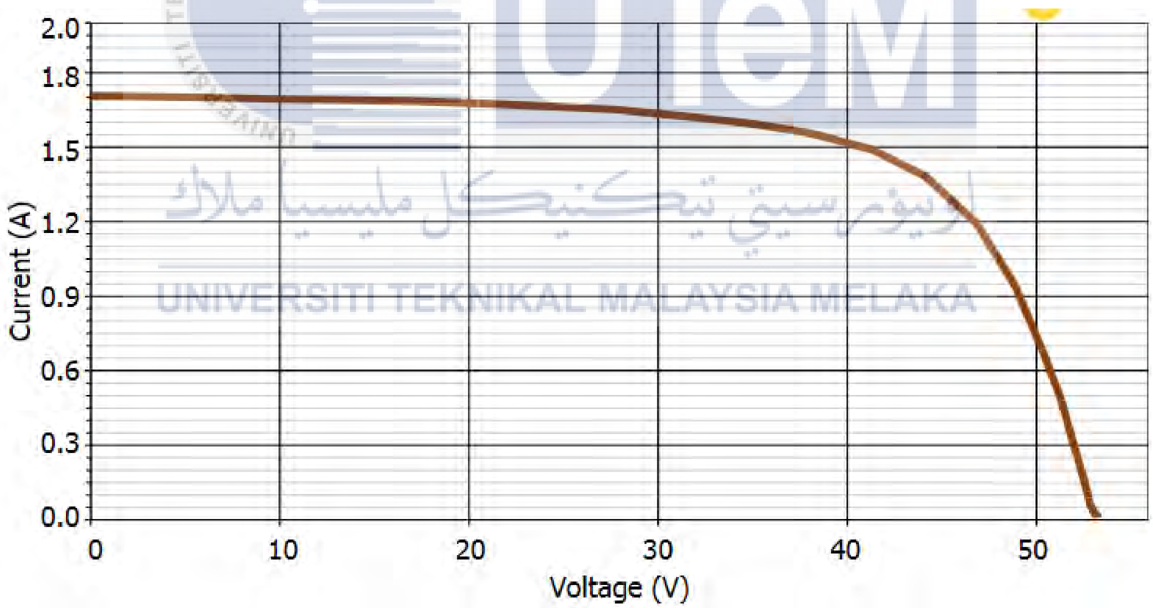


Figure 4.5: Graph I-V curve under irradiance of 700 – 800 W/m^2

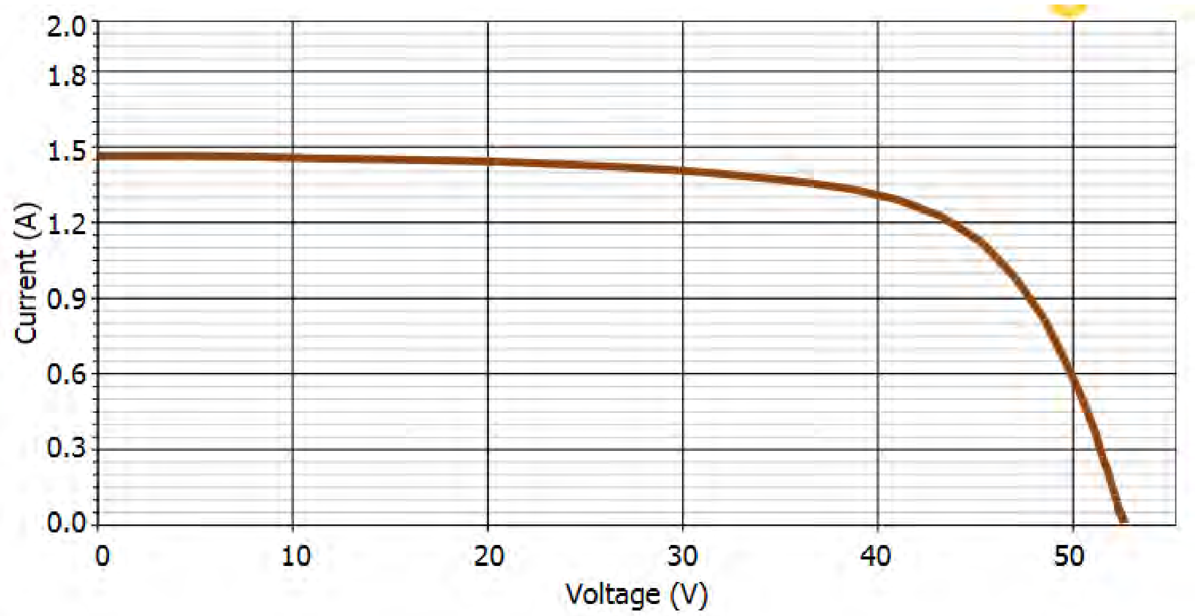


Figure 4.6: Graph I-V curve under irradiance of 600 – 700 W/m^2

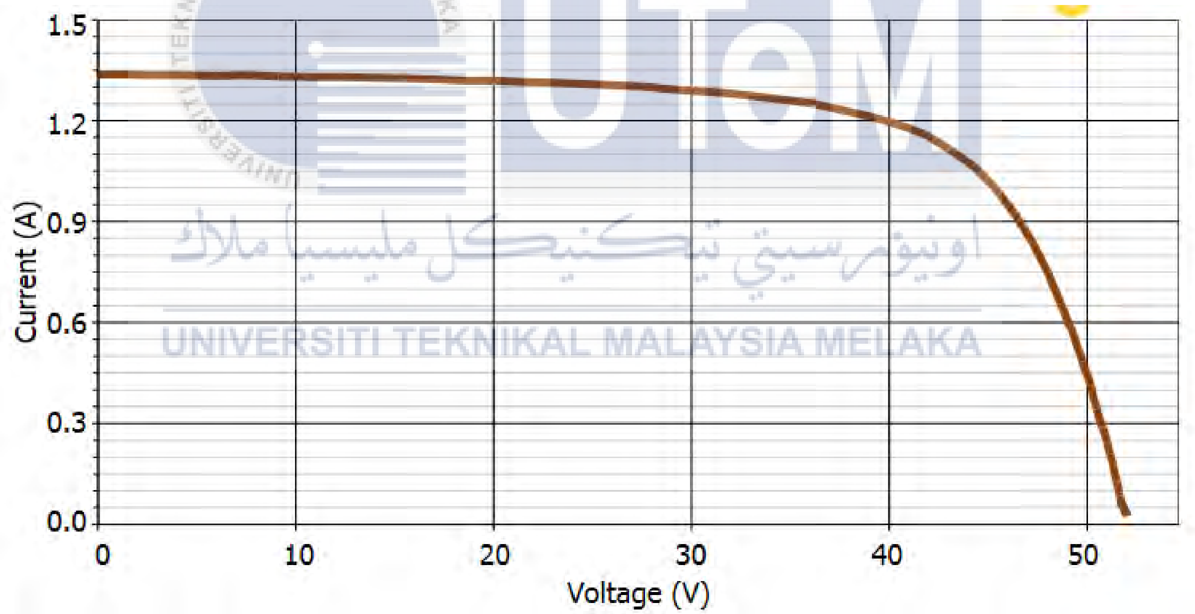


Figure 4.7: Graph I-V curve under irradiance of 500 – 600 W/m^2

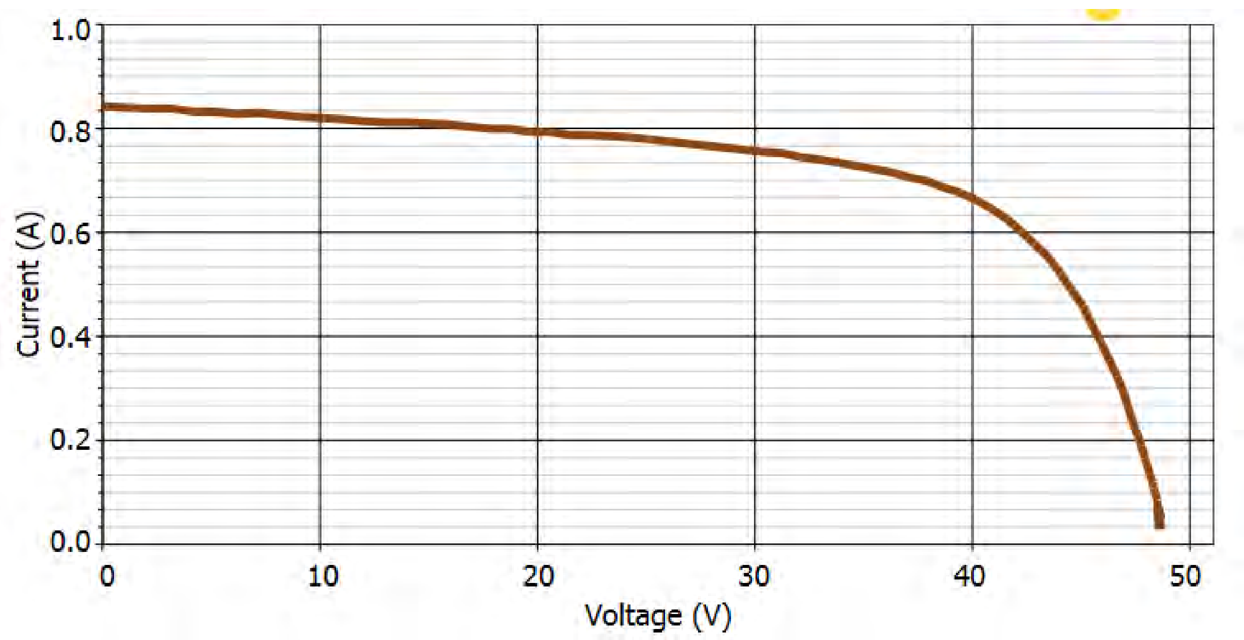


Figure 4.8: Graph I-V curve under irradiance of 400 – 500 W/m^2

Based on Figure 4.3 until Figure 4.8, the graph show the I-V curve of solar panel. Basically the PVA system is the kit that measured the parameter output of the solar panel. In this project, the software used to show the I-V curve from the irradiance needed and by using tinted film represent as cloud movement. Generally, the measurement by using this software was the same with Figure 4.1 and Figure 4.2 that show the V_{oc} and I_{sc} and translate it in term of I-V curve. From the highest irradiance to lowest irradiance, the current decrease from 2.19A to 0.84 and the voltage was around 49.72 and above.

4.3.2 80% of Tinted Film

Next, 80% of tinted film had been used to carried the output measurement of V_{oc} and I_{sc}. By comparing the value measurement without using tinted film which is 54.62V under irradiance of 900 -1000 W/m^2, the lowest V_{oc} that had been record was 54.75V under irradiance 400 – 500 W/m^2. This is due to the irradiance level that change from time to time. Figure 4.9 and Figure 4.20 illustrate the different value measurement of voltage and current based on the Table 4.4 below.

Table 4.4: Output value under 80% of tinted film

No.	G (W/m^2)	Without tinted film		With tinted film	
		V_{OC}, V	I_{SC}, A	V_{OC},V	I_{SC}, A
1.	400 – 500	53.17	2.13	54.75	0.93
2.	500 – 600	54.29	2.26	55.27	1.35
3.	600 – 700	55.36	2.32	55.11	1.46
4.	700 – 800	55.60	2.70	55.88	1.70
5.	800 – 900	54.71	2.80	55. 67	1.90
6.	900 – 1000	54.62	3.09	54.84	2.27

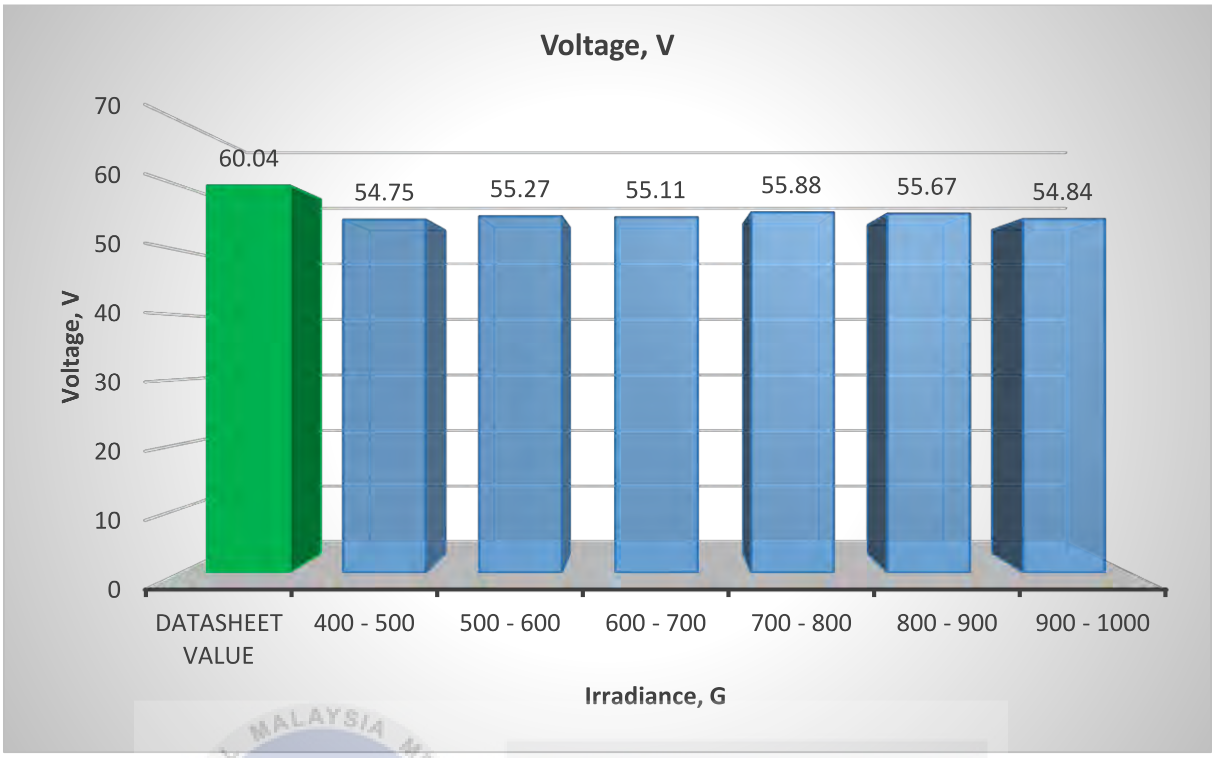


Figure 4.9: Graph voltage measurement under 80% of tinted film

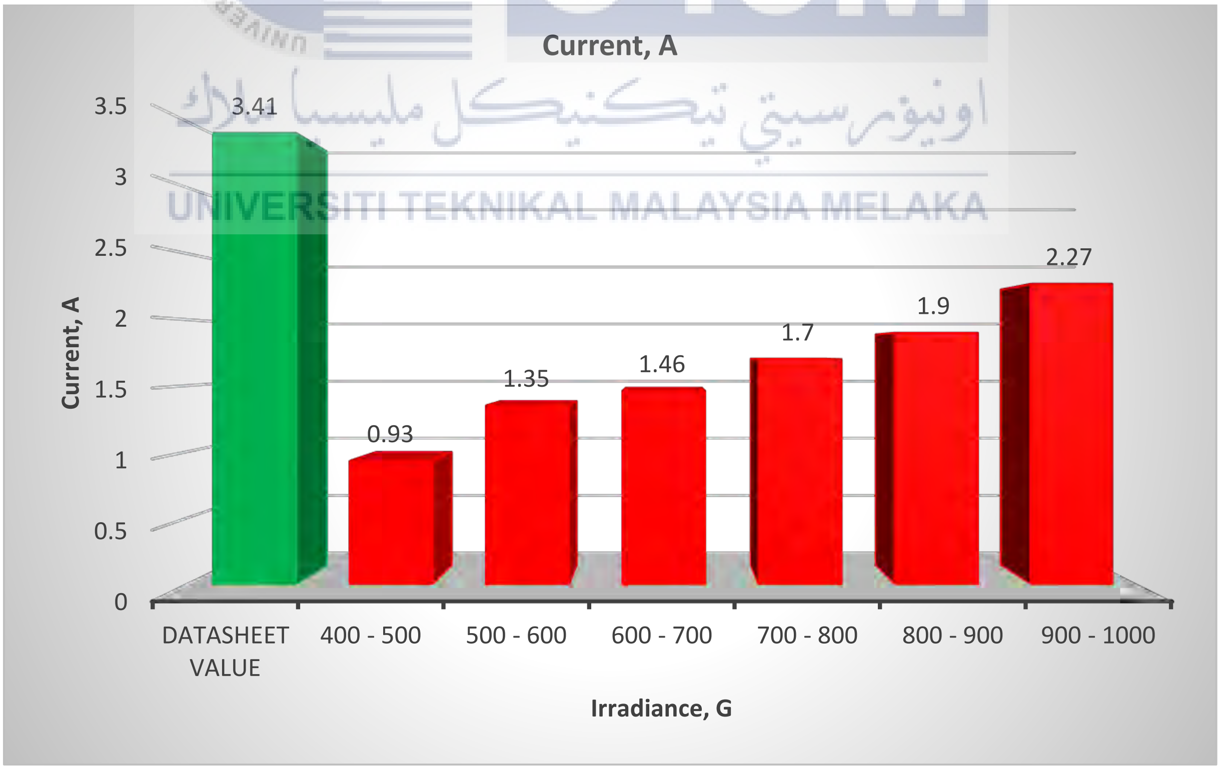


Figure 4.10: Graph current measurement under 80% of tinted film.

4.3.3 65% of Tinted Film

The output measurement of V_{oc} and I_{sc} had been record in Table 4.5 below. The voltage does not exceed below 53.17V and for the current was 1.27A at the lowest irradiance of 400 – 500 W/m^2.

Table 4.5: Output measurement under 65% of tinted film

No.	G (W/m^2)	Without tinted film		With tinted film	
		V_{OC}, V	I_{SC}, A	V_{OC}, V	I_{SC}, A
1.	400 – 500	53.17	2.13	55.27	1.27
2.	500 – 600	54.29	2.26	55.21	1.41
3.	600 – 700	55.36	2.32	55.97	1.83
4.	700 – 800	55.60	2.70	56.34	1.90
5.	800 – 900	54.71	2.80	55.55	2.10
6.	900 – 1000	54.62	3.09	54.89	2.37

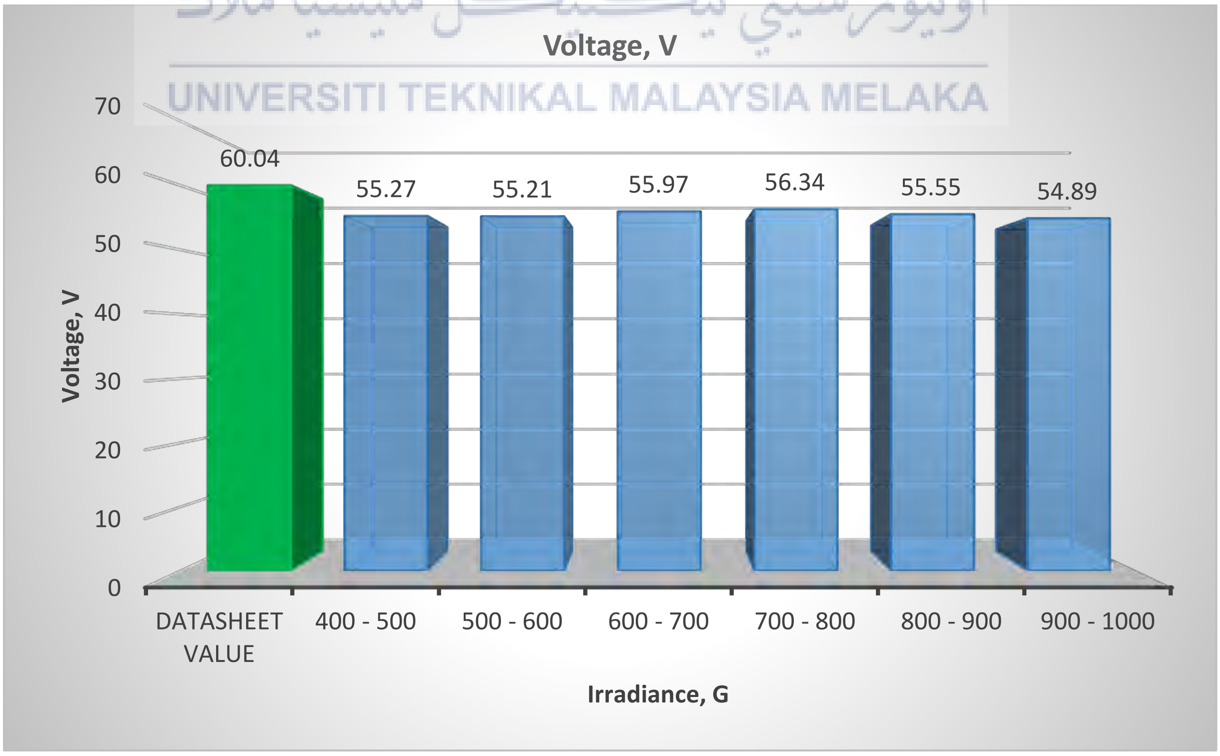


Figure 4.11: Graph voltage measurement under 65% of tinted film.

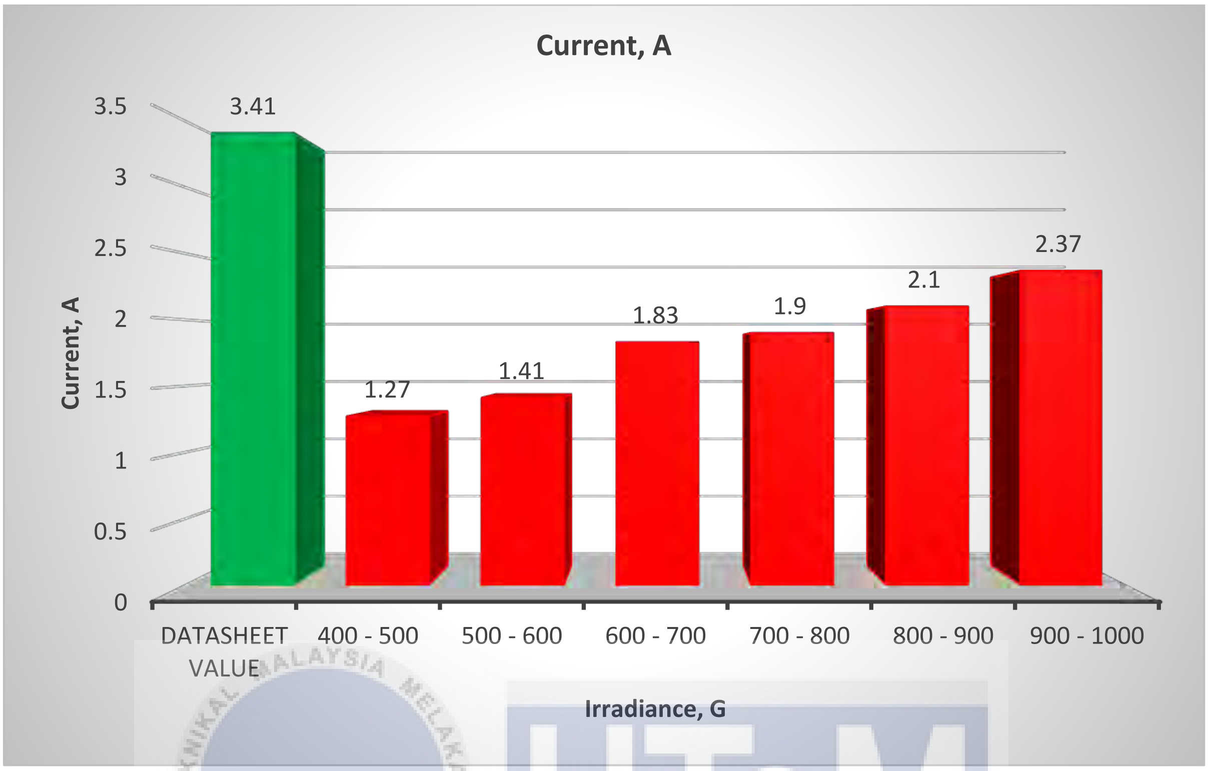


Figure 4.12: Graph current measurement under 65% of tinted film

As shown in Figure 4.11 and Figure 4.12 above, it show the graph of voltage and current under 65% of tinted film. For the voltage, the value that had been measured was from 54.89V to 56.34V which is marginally affected due to the temperature. While for the current measurement, it decrease with the low irradiance. At range of 900 – 1000 W/m^2 irradiance, it show the value of 2.37A from the 3.41A for the actual value.

4.3.4 50% of Tinted Film

At the lowest percentage of tinted film, the output had been carried out as shown in Table 4.6 below. Basically, under 50% of tinted film, the irradiance had increase through the film to hit the solar panel. From that, about 82% of irradiance for solar panel to operate and the highest voltage was 55.60V and the current was 3.09A.

Table 4.6: Output measurement under 50% of tinted film

No.	G (W/m^2)	With tinted film		Without tinted film	
		V_{OC}, V	I_{SC}, A	V_{OC} (V)	I_{SC} (A)
1.	400 - 500	53.17	2.13	56.34	1.34
2.	500 - 600	54.29	2.26	56.22	1.55
3.	600 - 700	55.36	2.32	57.01	2.34
4.	700 - 800	55.60	2.70	57.72	2.36
5.	800 - 900	54.71	2.80	57.96	2.48
6.	900 - 1000	54.62	3.09	58.15	2.71

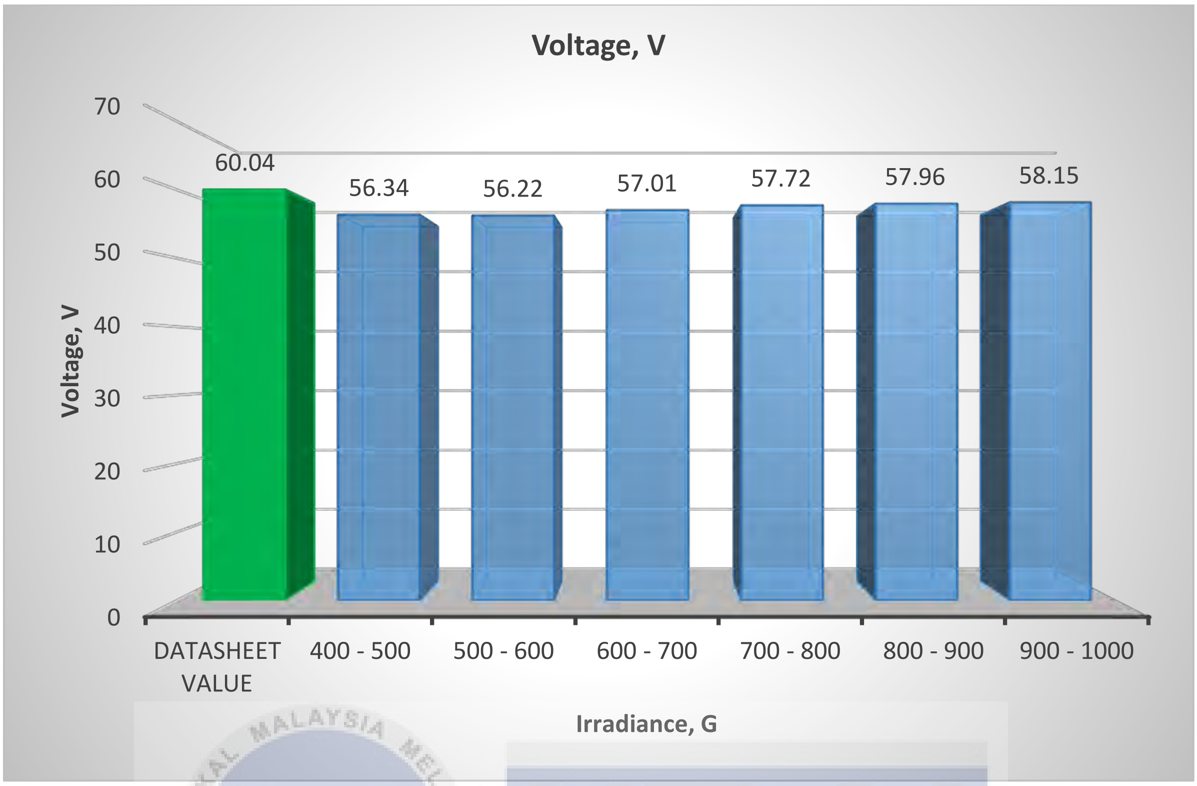


Figure 4.13: Graph voltage measurement under 50% of tinted film

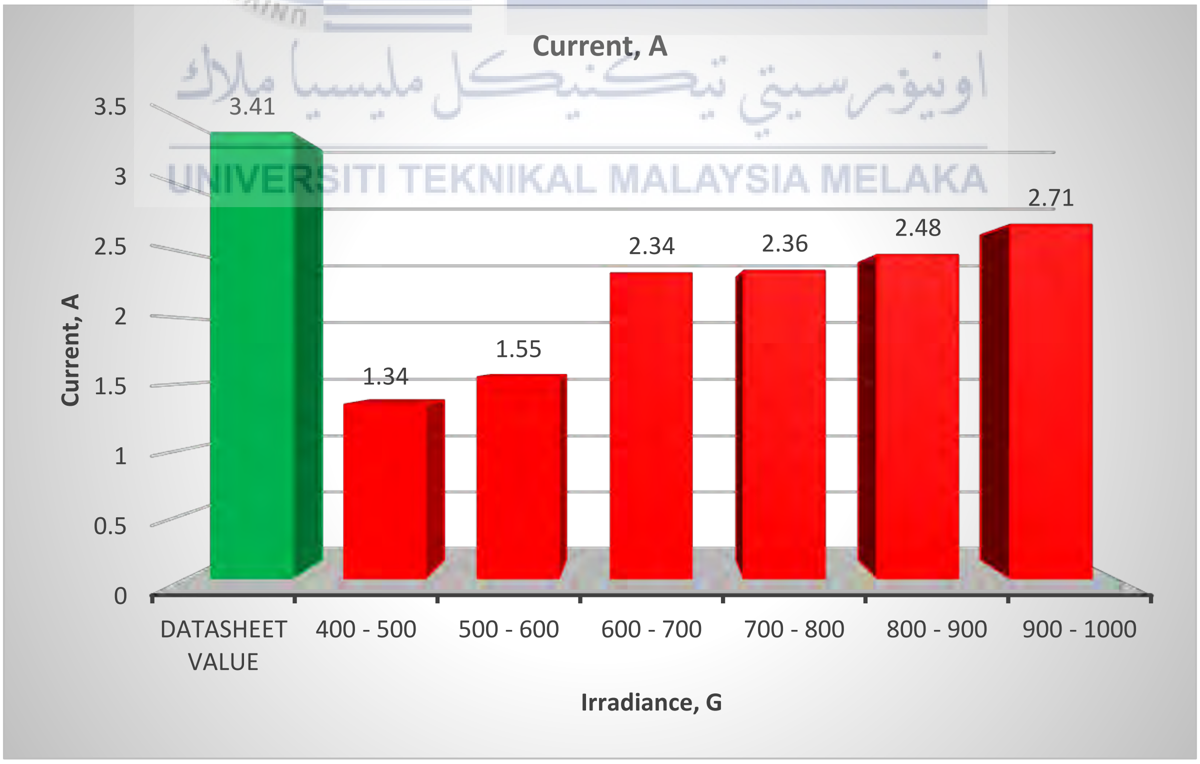


Figure 4.14: Graph current measurement under 50% of tinted film

4.4 Analysis from the result

4.4.1 Output value at highest irradiance, G = 900 – 1000 (W/m^2)

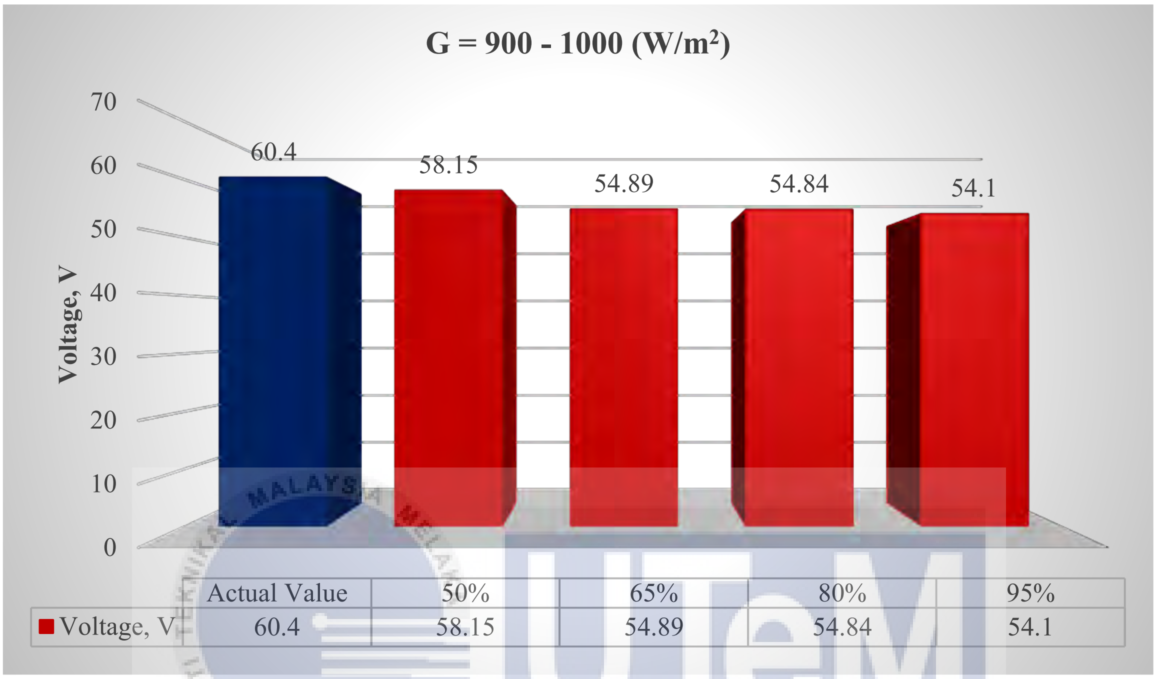


Figure 4.15: Graph voltage value at highest irradiance

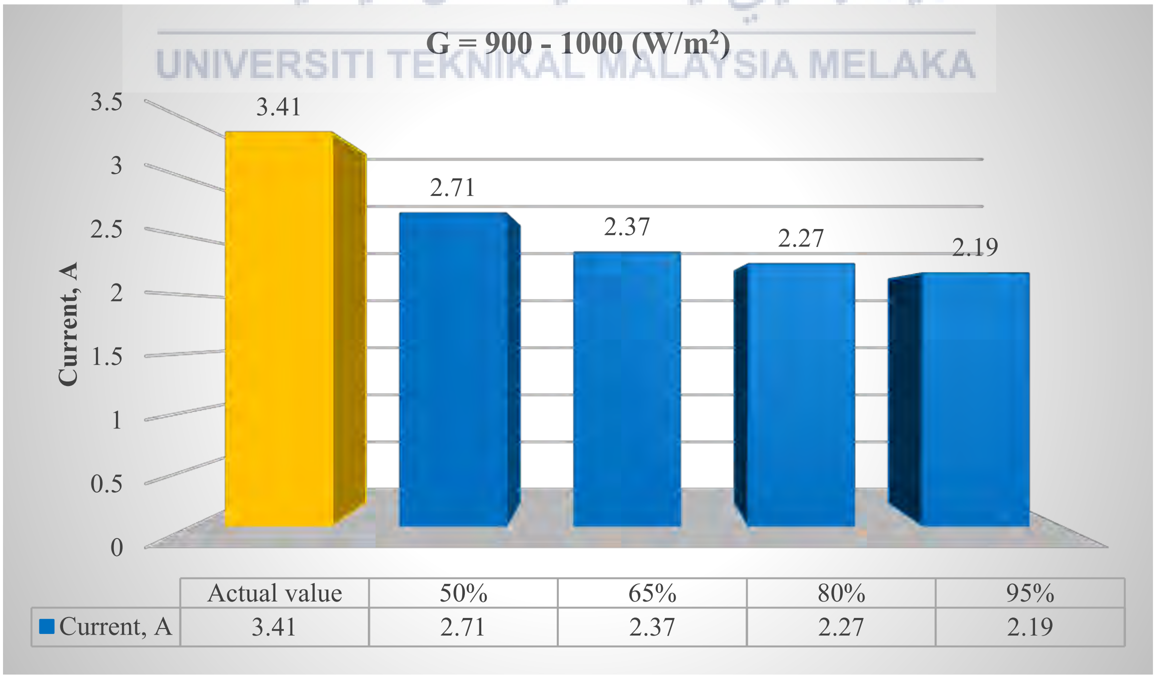


Figure 4.16: Graph current value at highest irradiance

From figure 4.15 above, it show that the relation between the solar irradiance of V_{oc} and I_{sc}. The voltage and current had been measured by using clamp meter and the irradiance was measured by Seaward Meter. Solar panel model NS-130G5 had being used for this project. It can be shown that the module current increase as the solar irradiance increase. But, by adding tinted film represent as cloud movement, the current had decrease due to the diffusing of tinted film. For voltage open-circuit, it show that the value was marginally affected. The voltage under irradiance of 900 – 1000 W/m^2 was between 54.1V to 58.15V. The V_{oc} of the solar panel was decreased by 11% from their actual value.

For the I_{sc} value as shown in Figure 4.16, the current marginally increase with an irradiance increase of the solar module. It show that the current is sensitive to the irradiance. The actual current for the solar panel was 3.41A and after affected it by tinted film, the value dramatically decrease about 2.19A to 2.71A under four different tinted layer represent as cloud.

4.4.2 Output value at lowest irradiance, G = 400 – 500 (W/m^2)

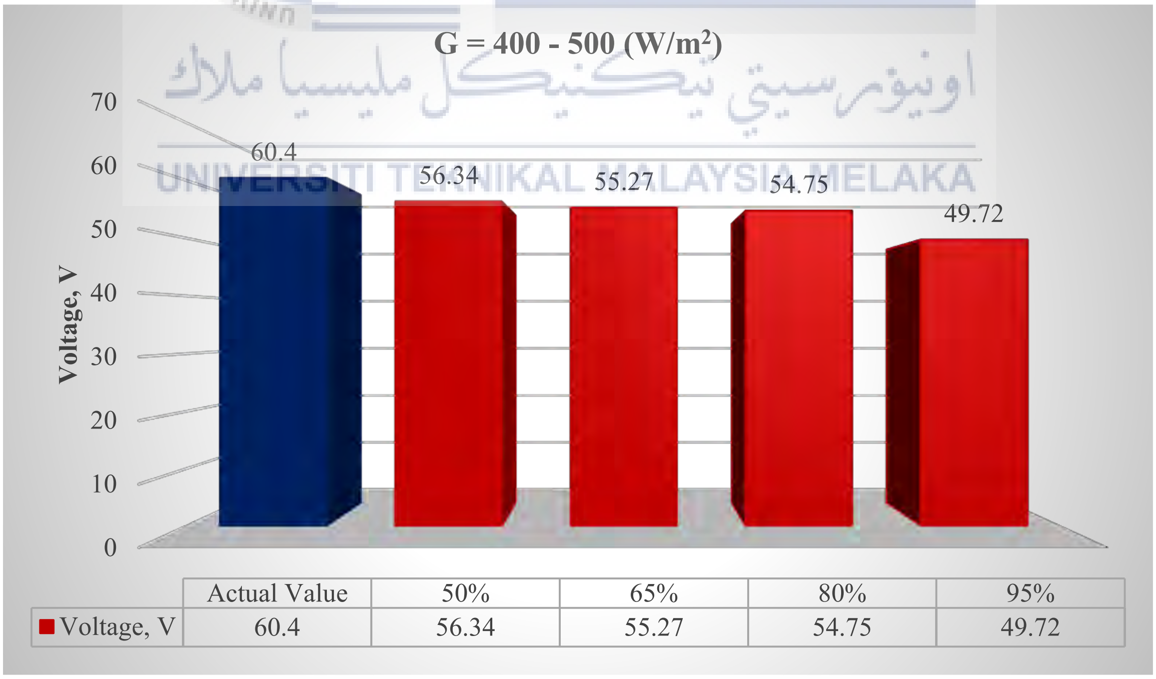
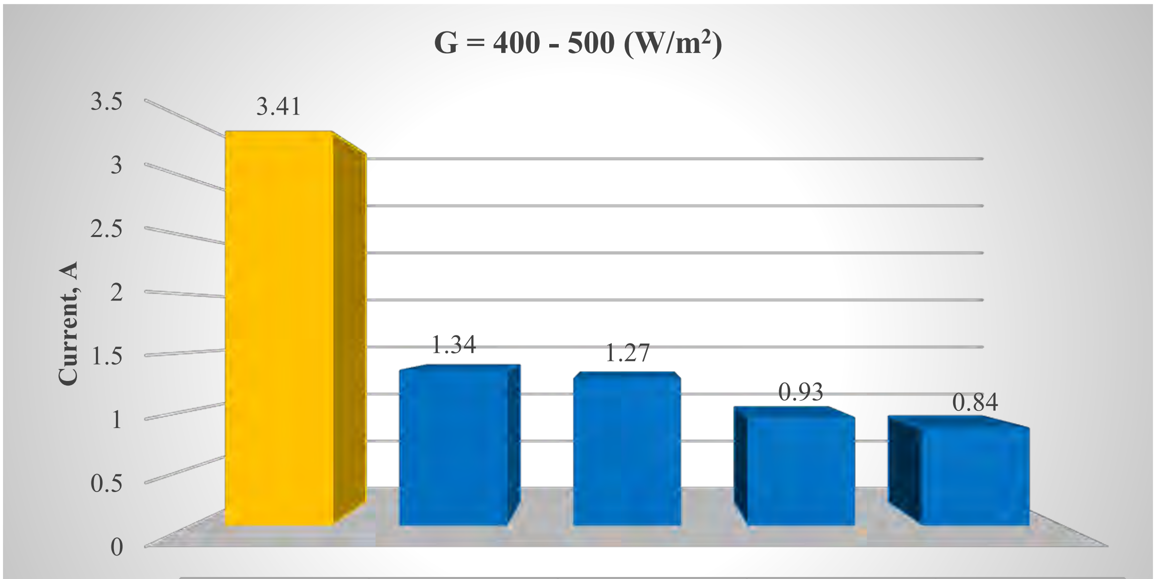


Figure 4.17: Graph voltage value at lowest irradiance



	Actual value	50%	65%	80%	95%
Current, A	3.41	1.34	1.27	0.93	0.84

Figure 4.18: Graph current value at lowest irradiance

From Figure 4.17 and Figure 4.18 above, the irradiance level had been decrease under solar irradiance of 400 – 500 W/m^2. Moreover, by using film tinted of 95%, 80%, 65% and 50% the current value had decrease between 1.34A and 0.84A. This is due to the low irradiance capture on this project. By referring to solar radiation collection at faculty, it may help at what time exactly suitable to run the project under 400 – 500 W/m^2. The measured voltage was between 49.72V to 56.34V. Slightly different with the voltage compared to the irradiance under 900 – 1000 W/m^2 but it is not a big change of V_{oc} compared to the actual value which is 60.4V under STC.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In a nutshell, a training simulation of various level of irradiance on the solar photovoltaic module was introduced in this final year project. By referring to the data collection of irradiance level from solar laboratory, it help a lot to know the suitable various irradiance from the lowest to the highest irradiance. The irradiance change from time to time and cannot been predict. From that, the effect of solar photovoltaic module output can been carried out. The results show that the irradiance level is an important rule for the solar photovoltaic module output. With the various percentage of the tinted film, the irradiance had been diffuse due to the blocking from the tinted film layer.

Solar panel model NS-130G5 had been use in this final year project to generating different values of voltage and current. Theoritically, when the irradiance increase, the current output also increase. But with the use of various of tinted film that simulate the cloud, the higher the percentage of tinted film, the output for the current decrease otherwise the tinted film at the lower percentage, the current had increase. Results as shown in chapter 4 support the theoritically that current marginally increase with an irradiance with an increase in module temperature. For the voltage, it show that the voltage doesn't change a lot because voltage significantly decrease with an increase of module temperature.

REFERENCES

[1] Gan Chin Kim and Kyairul Azmi Baharin (UTeM), Tan Pi Hua (Sharp), Two-Day Course on Grid-Connected Solar Photovoltaic System

[2] World Meteorological Organization (WMO). "Classification of cloud structure," WMO, 2014. [Online]. Available: https://www.wmo.int/pages/index_en.html.

[3] United Nation Development Programme, "Overview of policy instruments for the promotion of renewable energy efficiency in Malaysia," in Background Report, 2005.

[4] Richard G. Born, Northern Illionis University, Operation Management and Information System.

[5] Kribus, A. (2002). A high-efficiency triple cycle for solar power generation solar, 72 (1), 1-11.

[6] Cheiw Yun Law, Chin Kim Gan, Mohamad Fani Sulaiman, Kyairul Azmi. (2015). A Review On The Impact Passing Clouds

[7] A. Johari, S. Siti Hafshar, M. Ramli and H. Hashim, Potential Use of Solar Photovoltaic in Peninsular Malaysia, Universiti Teknology Malaysia, 2011

[8] Ismail, Dr, "An overview of the the renewable energy and energy efficiency blueprint for Iskandar Malaysia," in Minggu Sains dan ICT Negeri Johor at Iskandar Regional Development Authority, 21-27 June 2010.

[9] KeTTHA (Ministry of Energy, Green Technology and Water, Malaysia), "MBIPV project," available at http://www.mbipv.net.my/default.asp, cited on 23.02.2011.

[10] Saidur, R, Hasanuzzaman, M. Sattar, M.A, Masjuki, H.H, Irfan Anjum, M. and Mohiuddin, A.K.M, "An analysis of energy use, energy intensity and emission at the industrial sector of Malaysia," in International Journal of Mechanical and Materials Engineering (IJMME), vol. II (I), 2007, pp. 84-92.

[11] National weather service and National Oceanic and Atmospheric Administration, "Ten basic cloud type," Cloudwise. [Online]. Available: http://www.srh.noaa.gov/srh/jetstream/clouds/cloudwise/types.html. [Accessed: 03-Mar-2015].

[12] Energy Commission, Electricity supply Industry in Malaysia, Performance and Statistical Information 2009. Putrajaya: Malaysia, 2009.

[13] Abdul, R.M. and Lee, K.T, "Energy policy for sustainable development in Malaysia," in the joint International Conference on Sustainable Energy and Environment (SEE). Hua Hin: Thailand, 1-3 December 2004.

[14] N.Z. Al-Rawahi, Y.H. Zurigat, and N.A. Al-Azri, "Prediction of hourly solar radiation on horizontal and inclined surfaces for Muscat/Oman," J. Eng. Research, vol. 8, pp. 19-31, 2011.

[15] E. Lorenz, J. Hurka, D. Heinemann and H.G. Beyer, "Irradiance forecasting for power prediction of grid-connected photovoltaic systems," IEEE J. Sel. Topics Appl. Earth Observations and Remote Sensing, vol. 2, pp. 2-10, Mar. 2009.

[16] Rosnani Affandia, Mohd Ruddin Ab Ghani, Chin Kim Ghan, Liaw Geok Pheng, "The Impact of the Solar Irradiation, Collector and the Receiver to the Receiver Losses in Parabolic Dish System," Science Direct, Procedia - Social and Behavioral Sciences 195 (2015) 2382 – 2390.

[17] Hecht, Eugene. (2000). Physics: Calculus. Pacific Grove, CA: Brooks/Cole

[18] Website "2010.igem.org/TeamCambridge".

[19] Sudhakar K, Noopur Jain, Shivani Bagga. "Effect of Colour Filter on the performance of solar photovoltaic module. 2013 International Conference on Power, Energy and Control.