CERTIFICATION OF APPROVAL

DEVELOPMENT OF PV BASED SOLAR RADIATION MEASURING DEVICE

BY

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(15082)

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Approved:

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references an acknowledgements, and that the original work contained herein have not undertaken or done by unspecified sources or persons.

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Meenal a/p Pradeep Kumar

ABSTRACT

The demand of electricity in Malaysia increases every year due to rapid economic development. Malaysia has started encouraging the use of renewable energy for electricity generation. For example in 10th Malaysia Plan, government has stated that renewable energy will contribute 5.5% of the total electricity generated. Besides that, government had also introduced a tariff call Feed in Tariff which encourages the users to utilize more renewable energy. Solar energy is one of the renewable energy sources that have a good prospect as we receive approximately 6 hours of sunshine every day and this make solar power generation as a good choice compared to other renewable energy. One of the drawbacks of solar energy is that this energy is not available when there is a demand. This is because the solar radiation receive fluctuates throughout the day. One of the reasons for this fluctuation is path of sun and the local meteorological conditions.

In this PV based solar radiation monitoring system is developed. The design needs a mathematical model to determine the relationship between the incoming solar radiation and output voltage of a photovoltaic module. Besides that, this project also focuses to design a PV based solar measurement system. The relationship between solar radiation and output voltage of PV module was determined by using repeated experiment which required data collection of solar radiation and output voltage PV module. The output voltage and solar radiation measurements is then compared and analysed. To model the linear mathematical equation, MATLAB and linear regression method is used. This mathematical model is then used to develop a monitoring solar radiation in a PV system. Besides that the PV module is also attached with accelerometer to measure the tilt angle that will receive the highest solar radiation. Commercially available solar radiation measuring device is relatively expensive and not affordable for all the user. In order to sustain the dynamic load, solar radiation measuring device is needed to measure solar radiation received by PV module.

ACKNOWLEDGEMENTS

I would like to use this opportunity to thank my supervisor, AP DR. Balbir Singh Mahinder Singh for his continuous support, exemplary guidance and encouragement throughout my research.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Energy is a property of objects, transferable among them via fundamental interactions which can be converted but not created or destroyed. Example of energy that is available is potential energy, mechanical energy, electrical energy, kinetic energy and many more. Electrical energy can be produced in many ways such as from chemical reactions, heat, or light. Electricity is part of electrical energy and electricity is very essential to people around the world nowadays as it is the main needs in most of the activities in Malaysia. Electricity is used in industry, agricultural, transportations and many more. In conjunction in that, the total consumption of electricity increases every year. Figure 1 shows the total Electricity Consumption in Malaysia from 2005 to 2013.

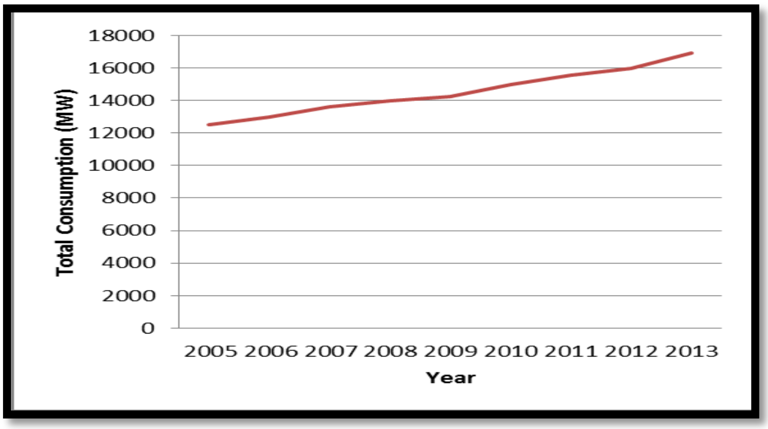


Figure 1: Total Electricity Consumption

In 2005,the total electricity consumption was 12493MW and increases till 16934MW in 2013. The increase in total electricity consumption is about 35.5% from 2005 to

2013. The increase in energy consumption every year is due to the rapid economic development. In Malaysia, electrical power generation is highly dependent on non-renewable fossil fuels. Table 1 shows the generation of electricity in Malaysia. In year 2011, almost 91.7% of electricity is generate using non-renewable fossil fuel such as natural gas, coal and oil [2]. The rise in costing of electricity production was contributed by the subsequent exhaustion of fossil fuels. Besides that usage of fossil fuels has various impacts on the environment. Some of the effects are greenhouse effect, global warming, and air pollution.

Table 1: Generation Mix in Malaysia [2]

Fuel	**2010**	**2011**	**2020**	**2030**
Natural Gas	54.2%	45.1%	47.8%	41.0%
Coal	40.2%	44.0%	48.3%	32.1%
Oil	0.2%	2.6%	0	0
Hydropower	5.1%	5.8%	3.9%	4.6%

Electricity generation from renewable energy sources need to utilize renewable and non-renewable energy equally. In 10th Malaysia Plan (2011-2015), plan number 9, the government has stated that renewable energy will contributes 5.5% of the total electricity generated [3],[4]. Besides that, government has also introduced Renewable Energy bill to encourage more users to utilize renewable energy and Feed in Tariff is one of the solution to increase the usage and investments of renewable energy. Some of the benefits of FIT are [5]:

a) FIT will able to reduce the emission of carbon dioxide to the environment.
b) FIT help to secure an energy power supply.

Solar energy are renewable energy and have a great prospect to developed in Malaysia as Malaysia received approximately 6 hours of sunshine every day. In Malaysia, the annual average daily solar isolation received is between 4.21KWh/m^2 to 5.56kWh/m^2. The highest solar radiation is estimated at August and November that is 6.8kWh/m^2 while the lowest is 0.61kwWh/m^2 in December [6]. Therefore the usage of solar resources can be used for electricity generation.

1.2 Problem Statement

Malaysia receives abundant of sunlight on average every year and this make solar power generation as a good choice compared to other renewable energy. One of the main drawbacks that this energy source will be not available when there is a demand. This is because the solar radiation received varies throughout the day. In other hand, the local meteorological conditions such as cloudiness also affect the quality of solar radiation received on the surface of earth. Besides that the shading effect such as dust on PV cell, bird dropping, and rain stains on PV cell also affect the quality of solar radiation. The output voltage of PV module is highly depending on the amount received of solar radiation. The output voltage of PV module fluctuated due to the transient nature of solar radiation. Therefore it is important to measure the solar radiation because it will be used to design PV based solar electricity measuring system.

1.3 Objectives

The objectives of this project are:

a) To develop mathematical model to determine the relationship between the incoming solar radiation and output voltage of a photovoltaic module.
b) To design PV bases solar radiation measurement system.

1.4 Scope of Study

This project is to derive a mathematical model to get the relationship between solar radiation and output voltage of PV. This mathematical model can be obtained by several experiments to obtain data by using solar measuring sensor. The data that are collected are tabulated and graphs are drawn based on the data. These graphs are then analysed. The PV output voltage and solar radiation are measured and the data are analysed using MATLAB and linear regression analysis. Linear regression analysis is used to validate correlation with the actual data. All sizing analysis performed uses solar radiation data that is obtain from UTP.

1.5 Project Relevancy

The monitoring device will be able to compute the value of solar radiation based on the output from PV module. This will reduce the need to use expensive solar radiation measuring devices such as pyranometer, pyrheliometer, sun shine recorder and many more. Besides that, this monitoring device is able to use anywhere and by anyone.

CHAPTER 2
LITERATURE REVIEW

In this chapter, I will discuss about the theoretical part of my projects. Some of the theoretical parts that will be discussed are Solar Radiation, Solar Geometry, Solar Panel System, Monitoring System and types of measuring devices available in the market.

2.1 Solar Radiation

The solar radiation that strikes on the earth surface fluctuates. This is due to the time of the day, local meteorological and the apparent trajectory of the earth on its orbit. Solar radiation is the electromagnetic radiation emitted by the sun. The wavelength of the radiation is between 280 nm to 4000 nm [8]. Solar radiation is the energy received from the sun and this energy is the intensity of sun rays falling per unit time per unit area. The particles are absorbed, scattered and reflected when the radiation hit the clouds in the atmosphere. These particles consist of air, dust and pollutants. When the particles are scattered, a radiation is form and it is known as direct radiation or beam radiation. It has a definite direction. Reflection occurs in the atmosphere and Earth's surface. Radiation reflected back to the ground is known as reflected radiation. The reflection of solar radiation depends on the nature of the reflecting surface [9]. The fraction of the solar irradiation that is reflected to the surface of Earth is known as Albedo [9]. The scattered radiation from the beam radiation is known as diffuse radiation. The total of beam radiation (I_B), diffuse radiation (I_D) and reflected radiation (I_R) is global radiation [8], [9]. The type of radiation can be seen in Figure 2. The average global radiation is approximately $1000W / m^2$ at noon.

$$I_G = I_B + I_D + I_R \tag{2.1}$$

The percentage of diffuse radiation is 40% from the global radiation. The percentage of diffuse radiation increases if the atmospheric condition is cloudy or there is a pollution level in the atmosphere.

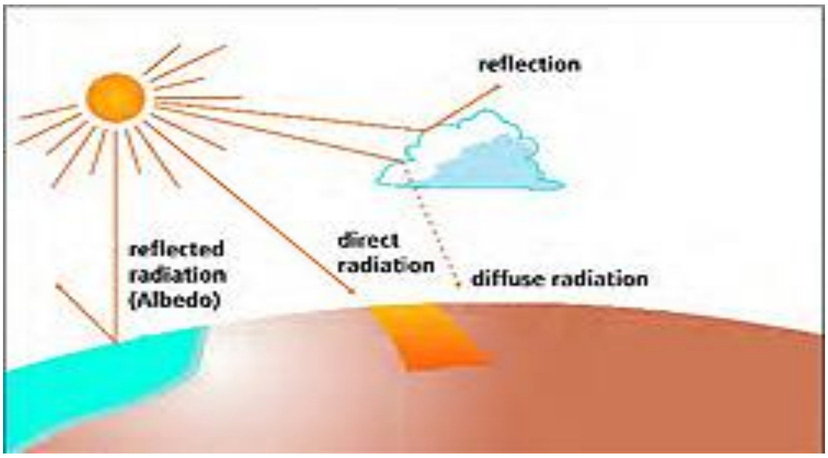


Figure 2: Components Solar Radiation

Malaysia is located 4.0° N. Malaysia is a country where its whether is hot and humid and one of the country in the world which received sun isolation throughout the year. The average solar radiation received in Malaysia is about 4.21kWh/m^2 to 5.56kWh/m^2.

2.2 Solar Geometry

The Earth rotates about the axis through North and South poles which is perpendicular to the equator. The position of sun plays a main factor that affects the amount of sunlight reaches a PV module on the earth’s surface. Plane of sun is the plane that is parallel to the Earth’s celestial equator and through the center of the sun. Angle of declination is the angle the center of earth makes in relative to the ecliptic plane of the earth. Angle of declination is from 23.5° to -23.5°.This angle of declination changes throughout the year. Figure 3 shows the yearly Variation of Declination angle.

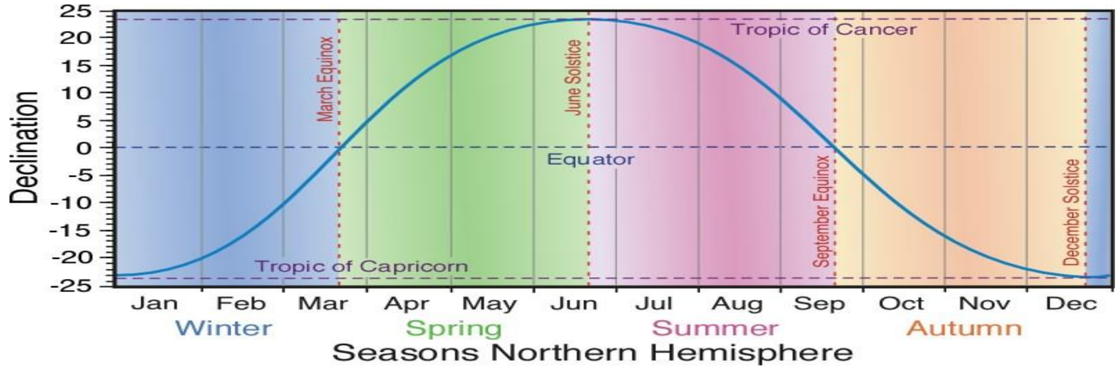


Figure 3: Yearly Variation of Declination [7]

Zenith angle, θ_z as shown in Figure 4 is the angle between the direct sunlight rays and the vertical of the ground. Azimuth angle, A is the horizontal angle on the surface of the earth measured clockwise from the north. Elevation angle, h is measured up from the horizon.

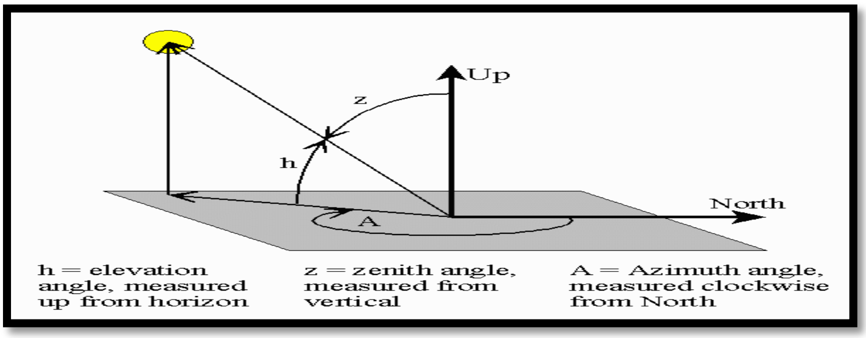


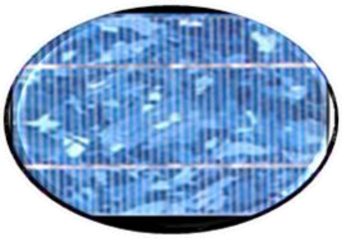
Figure 4: Zenith angle [7]

2.3 Solar Panel System

A solar panel is made up of many small solar cells. This solar cell consists of semiconductors which are usually silicon which has p-n junctions. Sunlight is made up of miniscule particles which are known as photons and usually have more energy compared to the semiconductors. When these photons which radiates from the sun hit the silicon atom of the solar cell, they will transfer their energy to the loose electrons and create electron hole airs on the p-n junction. Electricity is formed when the electron move from the n-side and end up in the p-side. In Malaysia, three type of PV cells are usually used which are monocrystalline silicon PV, polycrystalline silicon PV and thin film PV. Monocrystalline silicon PV has a highest efficiency level which is 13%-17%. Polycrystalline silicon PV has an efficiency of 11%-15% while Thin film PV has an efficiency of 7% - 10%.

The PV cell that will be using for this project is monocrystalline PV cell as it has higher efficiency compared to the other two PV cell that is available in the market. Besides that, monocrystalline silicon PV cell is more environmental friendly and able to reduce the amount of electricity used. Although the initial cost of monocrystalline silicon PV cell is more expensive than other PV cells, but it is the most efficient PV cell. The advantage and disadvantage of the PV cells are shown in the table 2 below.

Table 2: Advantage and Disadvantage of PV cells.

Type of PV Cells	Advantage	Disadvantage
Monocrystalline Silicon PV 	a) Longevity as it is the first generation of PV cells. b) The most efficient PV Cells. c) Environmental friendly. d) Reduce the amount of electricity.	a) Initial cost is more expensive than other PV Cells. b) It is fragile. This is because it can be broken easily by branches or even strong wind.
Polycrystalline Silicon PV 	a) Cost is lesser than monocrystalline Silicon PV. b) It is much simpler to manufacture. c) It is as reliable as Monocrystalline Silicon PV.	a) Less efficient.
Thin Film PV 	a) User Friendly b) Fewer defect as to produce thin film is simple. c) Manufacture Process is fast.	a) Newly discover so user are indecisive on the quality of the product. b) Space limitation because it consume space. c) Less efficient.

2.4 Monitoring System

The importance of monitoring system for Solar Electricity Generating System [SEGS] is to make sure that all devices that is connected to SEGS is functioning properly [10]. The PV monitoring system design that is available in Malaysia is highly dependent to the meteorological conditions. Besides that, the price of PV monitoring system in Malaysia is very costly [10], [11]. Therefore, the design of monitoring system should be cost effective and friendly to user where the monitoring system will be able to transmit the analysed data to the user and the transmitted data will be monitor by the user to ensure the SEGS is performing at is ideal level and the output received is always stable. To develop a monitoring system, Distributed Control System (DCS) should be integrated. Besides that, to develop a monitoring system:

a) The Photovoltaic Electricity Generating system consists of PV Panel, battery, charge controller and inverter.
b) Data acquisition system
c) Connection to internet to verify the data collected.

Two factors that affect the performance of the PV are temperature and the shading effect. When the temperature is high, the performance of PV reduces. Therefore, to maximize the PV, angle of incident play an important role. By this the PV panel will be able to focus toward the optimum solar radiation from the sun. There are few advantages of installing a monitoring system. Some of the advantages are provide an alert when the device fails to function and give some prediction of possible breakdowns

2.4.1 Pyranometer

Pyranometer is an instrument used to measure solar radiation that is already available in the market. It measures direct and diffuse solar radiation. It is a type of actinometer that is used to measure the broadband of solar radiation [14]. Besides that, its designed is to measure solar radiation from a field of view of 180°[14]. Pyranometer is cover with a spectral sensitivity that is usually as flat as possible [14]. Figure 5 shows the cross section of a pyranometer [15].

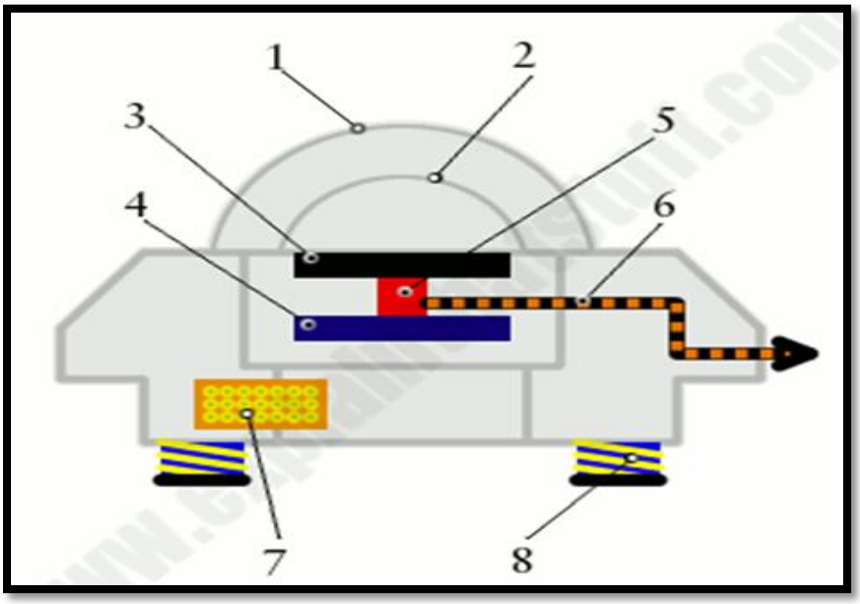


Figure 5: Cross Section of Pyranometer [15]

1. Outer dome

   It is made from a hemisphere of optical glass.

2. Inner dome

   It is made from a smaller hemisphere of optical glass.

3. Black carbon disk

   Its function is to absorb wavelength of solar radiation. Besides that it act as a sensing element and absorbs a broad range of wavelengths of solar radiation and acts as the sensing element. This control disk is illuminated by the Sun.

4. Control disk

   It is not illuminated by the Sun and its main function is for comparison and compensating element. When there is a temperature rise besides the solar heat, it will warm up both the disks equally.

5. Thermopile temperature sensor

   Its main function is to compare the temperature rise of the two disks.

6. Output lead

   It is usually about 10m or 30ft long.

7. Replaceable silica gel cartridge

   It absorbs moisture to prevent dew forming inside on cold nights.

8. <u>Adjustable screw legs</u>

   It able the level the pyranometer using its built-in. This built in sensitive to a fraction of a degree.

When sunlight falls on a pyranometer, the thermopile sensor produces a proportional response in not more than 30 Seconds [15]. The hotness of the sensor is depend of the amount of sunlight that reaches. The higher amount of sunlight, the hotter the sensor. Thus, the amount of electric current generate is greater. The advantage of thermopile is that its design which is precisely linear [15]. So if there is doubling of solar radiation, the amount of current produce is two times more than the original current produce. Pyranometer follows cosine response. This is because the electrical signal from the pyranometer varies with the cosine of the angle between the Sun's rays and the vertical [15]. For example, it produces maximum output when the Sun is directly up and zero output when the Sun is at dawn. Figure 6 shows how a pyranometer work.

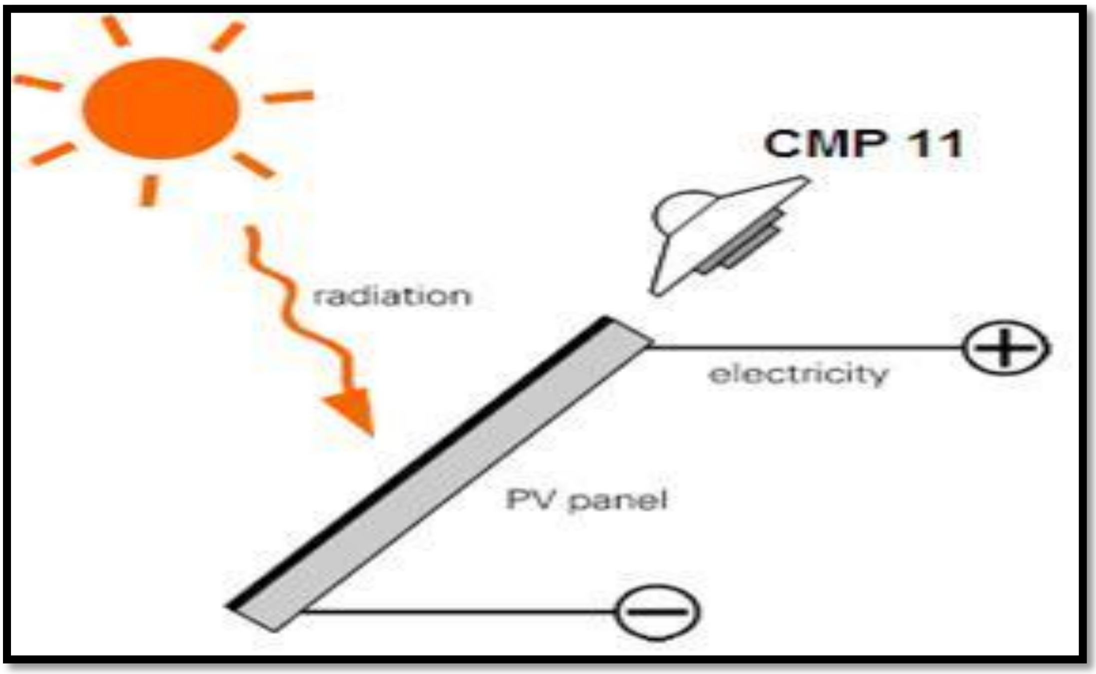


Figure 6: Pyranometer mechanism [15]

2.4.2 Pyrheliometer

A pyrheliometer is a measuring device that is used to measure direct solar radiation from 300-400nm at normal incident [16]. This instrument is used with a solar tracking system to keep this measuring device aimed at the sun [16]. Besides that, pyrheliometer is used for instantaneous measurements and continuous recording of direct solar radiation. Figure 7 shows the cross section of pyrheliometer [16].

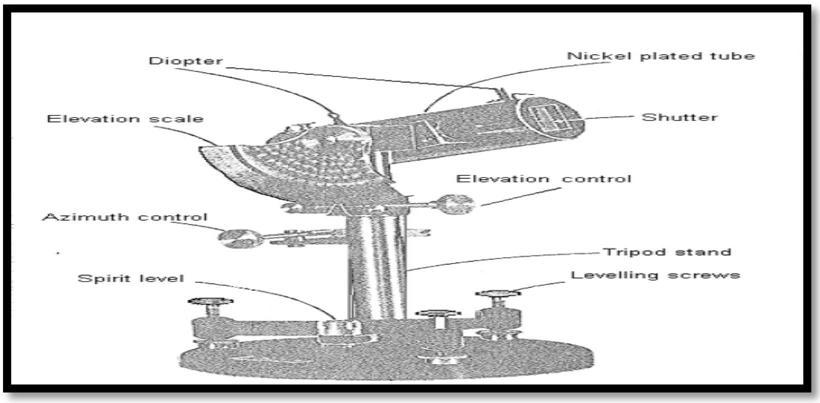


Figure 7: Cross Section of Pyrheliometer [16]

Pyrheliometer is made up of a cylindrical metal tube. The tube is mounted on a holder and knobs and is directed against the Sun. The right direction is controlled by the diopters. The height angle of the Sun may be read from the elevation scale. The levelling screws are used to obtain a correct height angle.

Sunlight enters the instrument through a window and is directed onto a thermopile which converts heat to an electrical signal that can be recorded [17]. The signal voltage is converted via a formula to measure watts per square metre. It is used with a solar tracking system to keep the instrument aimed at the sun [17]. A pyrheliometer is often used in the same setup with a pyranometer.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

3.1.1 Solar Radiation and PV Module Voltage

Solar simulator and IV tracer is used to verify the PV module specifications. The first step of the experiment is by placing the PV module at the solar tracker [4]. Then the type of PV Cell is decided. The type of PV Cell that will be using is monocrystalline PV Cell as it has the highest efficiency. Then the PV output voltages are measure and collect by using computerized acquisition system. The PV module is placed horizontally and the solar radiation is measured by pyranometer. The voltage and solar radiation are measured every 5 minutes. Next the data is analyzed using software called MATLAB to find the relationship between solar radiation and PV Module output voltage. A mathematical method called linear regression analysis method is used to validate correlation of the equation.

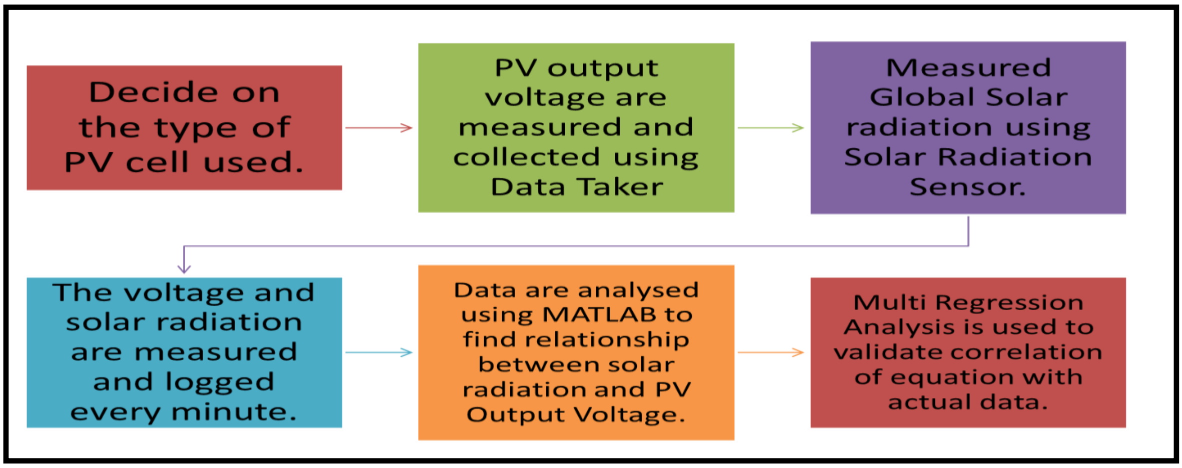


Figure 8: Flow Diagram of Solar Radiation and PV Module Voltage

3.1.2 Programming for Solar Insolation Measuring Device

A microcontroller is used to measure PV module output voltage and to calculate the solar radiation. There are many microcontrollers available in the market. The microcontroller that I will be using is Arduino .This is because it is user friendly.

3.1.3 Solar Radiation Measuring Device

The PV module is attached with a 3-axis accelerometer to measure the tilt angle that will receive the highest solar radiation. Accelerometer will able to measure the X-axis and Y-axis of PV module orientation as the amount of solar radiation depends highly on the tilted angle and orientation of PV module [4]. Figure 9 below shows the block diagram of solar radiation measuring device.

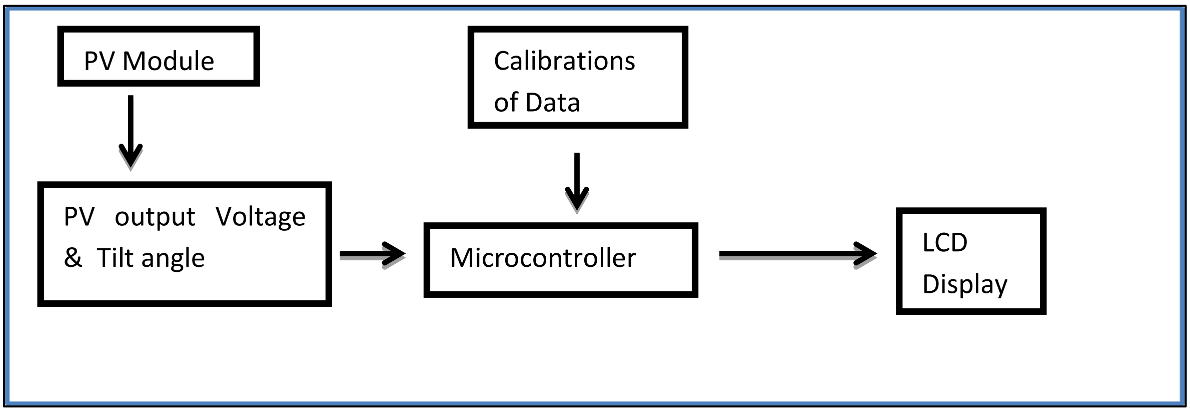


Figure 9: Solar Radiation Measuring Device [4]

3.2 Theoretical Development

3.2.1 Resource data analysis

The solar radiations are obtained for 7 days on 5 minutes basic to obtain the weekly average value. Figure 10 below show the average daily solar radiation in Universiti Teknologi PETRONAS (UTP).

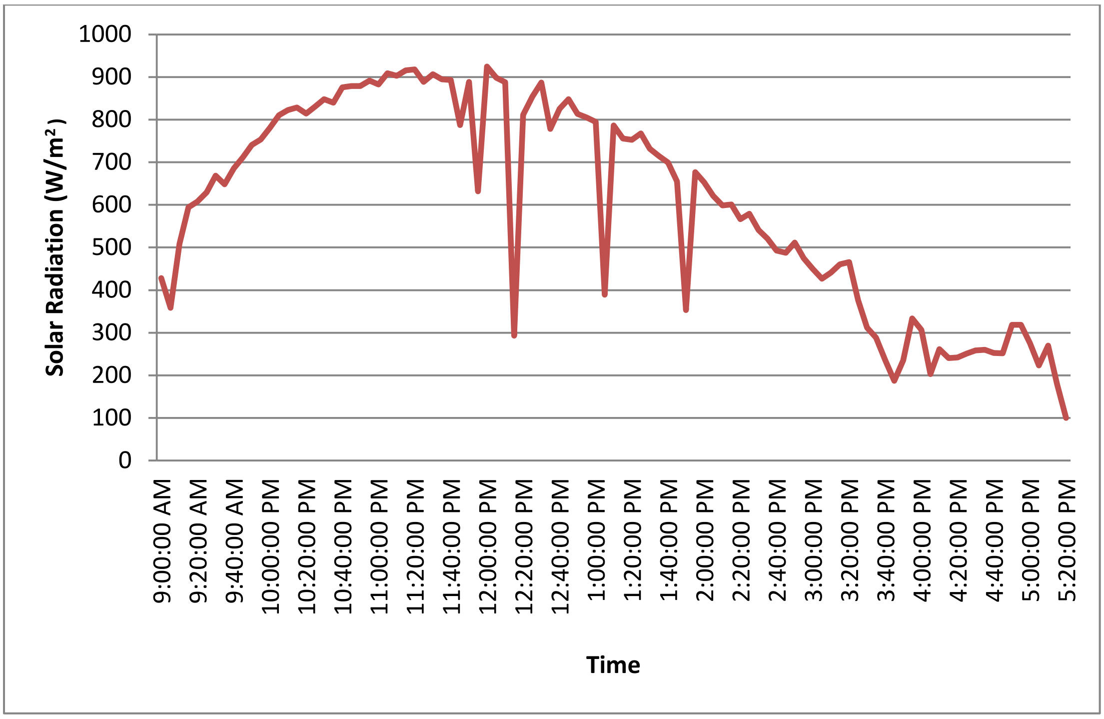


Figure 10: Average Solar Radiation in UTP

3.3 Key milestones

The key milestones for FYP 1.

Event or Deliverable	**Week**	**Responsibility**
Project Selection and Acceptance by Supervisor	Week 1-2	Discuss the project topic and approval of topic from Supervisor.
Project execution initiated	Week 2-5	Research of project. Understanding theories such as solar geometry, solar radiation, SEGS.
Submission of Extended Proposal	Week 6	Submission of Extended Proposal to FYP Coordinator
Proposal Defense (Seminar Presentation)	Week 8-9	Report on the progress of project to supervisor, fellow students and other lecturer.
Project execution continued	Week 10-12	Continue on project activities
Submission of Interim Report	Week 14	Hand in Interim Report to FYP Coordinator
FYP 2		

The Key milestones for FYP 2.

Event or Deliverable	Week	Responsibility
Completion of MATLAB and Multi regression method.	Week 1-2	By using the data collected during FYP 1, tabulate and perform MATLAB and multi regression.
Preparation of Mathematical Model	Week 2-5	Produce a mathematical model equation with high accuracy.
Accelerometer Assembly and Programming	Week 6	Assembly the accelerometer and programmed the accelerometer.
Progress Report (Submission)	Week 7	Report on the progress of project to supervisor by submitting a progress report.
LCD Display Programming	Week 8-10	Continue project activities by programming the LCD Display
Testing and Verification	Week 10	Testing and verification process is done.
Final Report	Week 11	Submit Final Report of FYP

3.4 Project Work

The project work to achieve the objectives was divided into 2 parts. The mathematical model to determine the relationship between the incoming solar radiation and output voltage of PV module. The next part is to design a solar radiation measurement system. Besides that, this measurement system is also added with another feature where it is able to calculate the maximum tilt angle that will receive the highest solar radiation on that specific time and day.

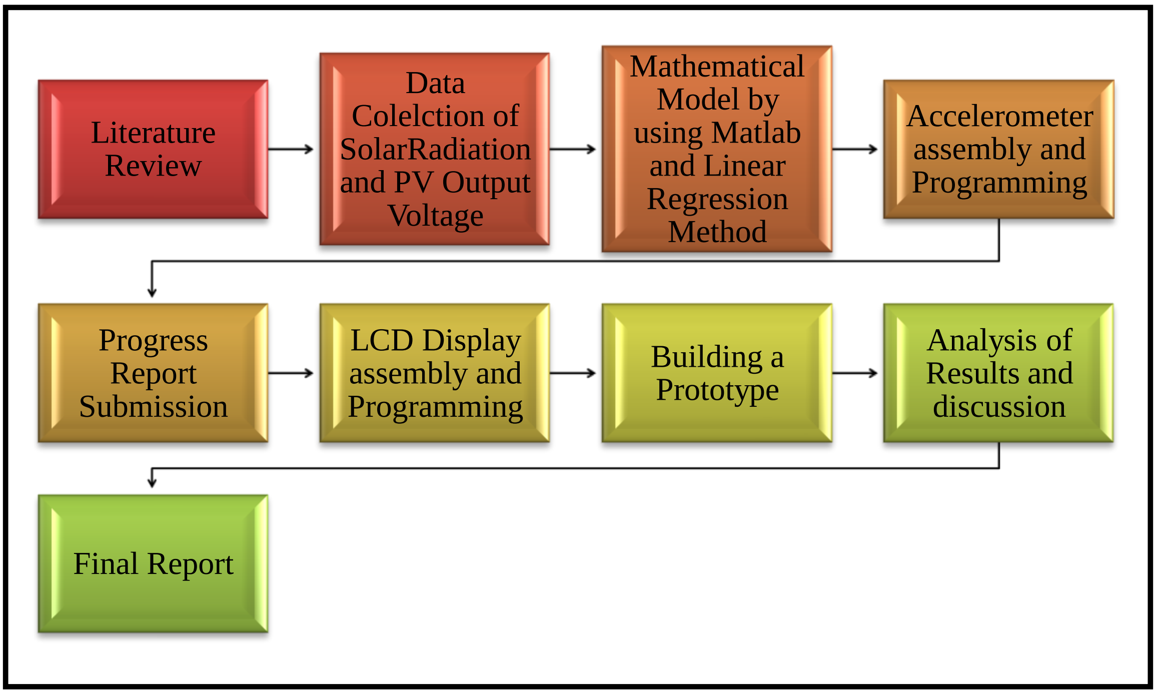


Figure 11: Project Flow for FYP

3.5 Gantt Charts

No	Detail	Week (FYP 1)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Title Selection and Allocation														
2	Submission of Title Selection Form														
3	Title and Supervisor Allocation														
4	Preliminary Research Work														
5	Preparing Extended Proposal														
6	Submission of Extended Proposal														
7	Proposal Defence														
8	Project Work Continues														
9	Submission of Interim Draft Report														
10	Submission of Final Interim Report														

No	Detail	Week (FYP 2)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Completion of Matlab and multi regression analysis														
2	Preparation of Mathematical model														
3	Accelerometer assembly and Programming														
4	Literature Review														
5	Progress Report Submission														
6	LCD Display Programming														
7	Testing and Verification														
8	Draft Final Report Submission														
9	Final dissertation submission														

3.6 Tools and Software

Some of the tools are already available while some of the tools need to be bought from the electronic shop. Table 3 shows that list of tools and software used.

Table 3: List of Software and Tools

Solar Radiation and PV Output Voltage	
Hardware	Software
• Data Taker Set • Solar Radiation sensor • Tripod	• Data Taker Web interface for monitoring and configuration.
Solar Measuring Device	
Hardware	Software
• Photovoltaic Cell • Arduino • Accelerometer	• Microcontroller • Matlab • Arduino

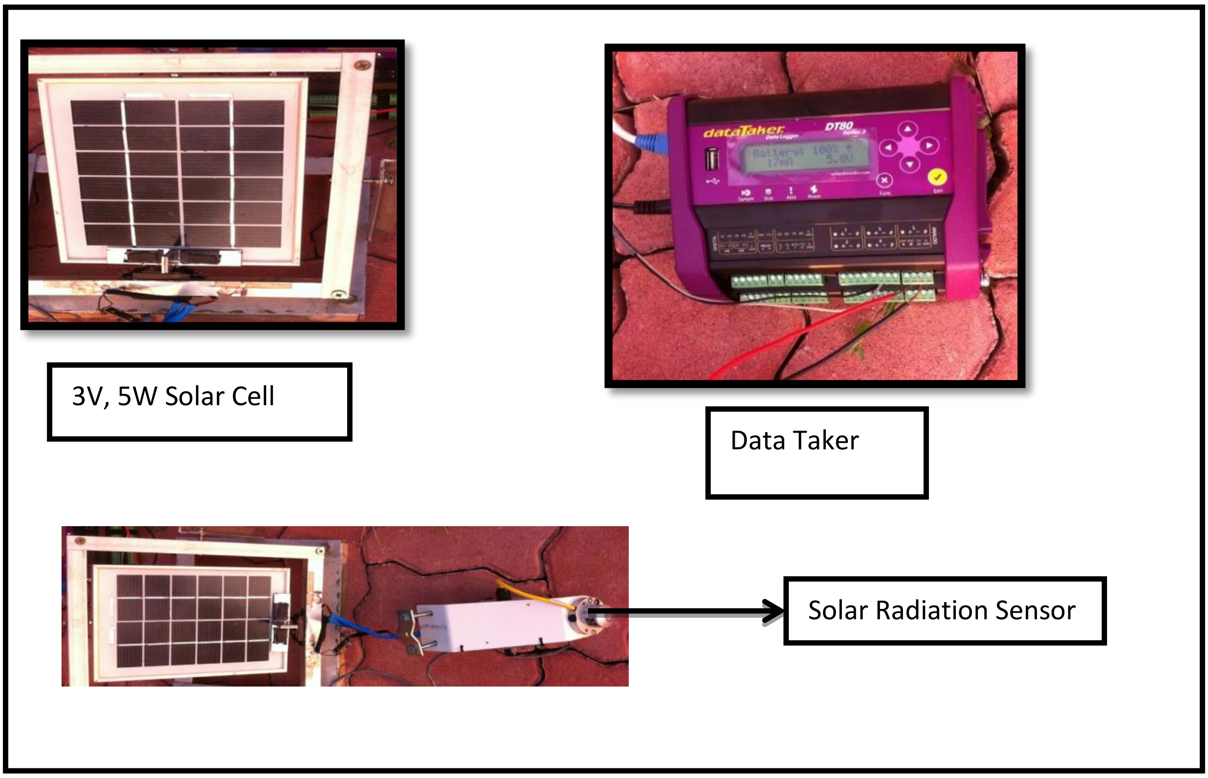
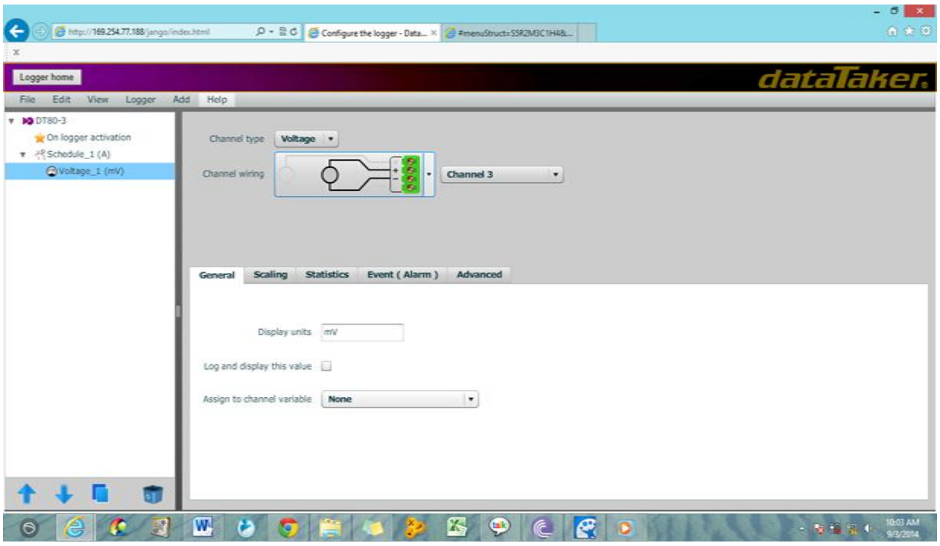
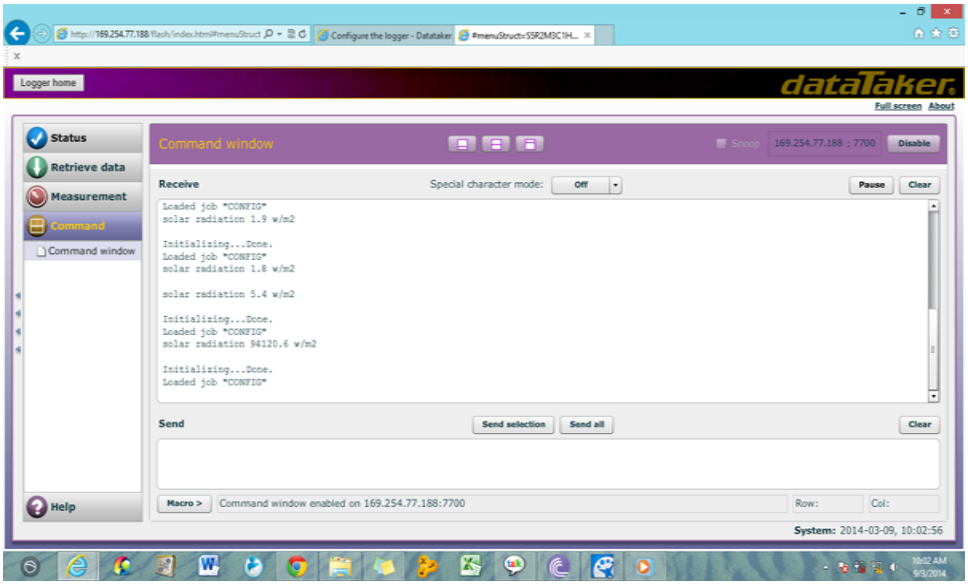


Figure 12: Tools Used for Experiment



Configuration of Data Taker Window



Monitor Data Taker Window

Figure 13: Software Snapshot

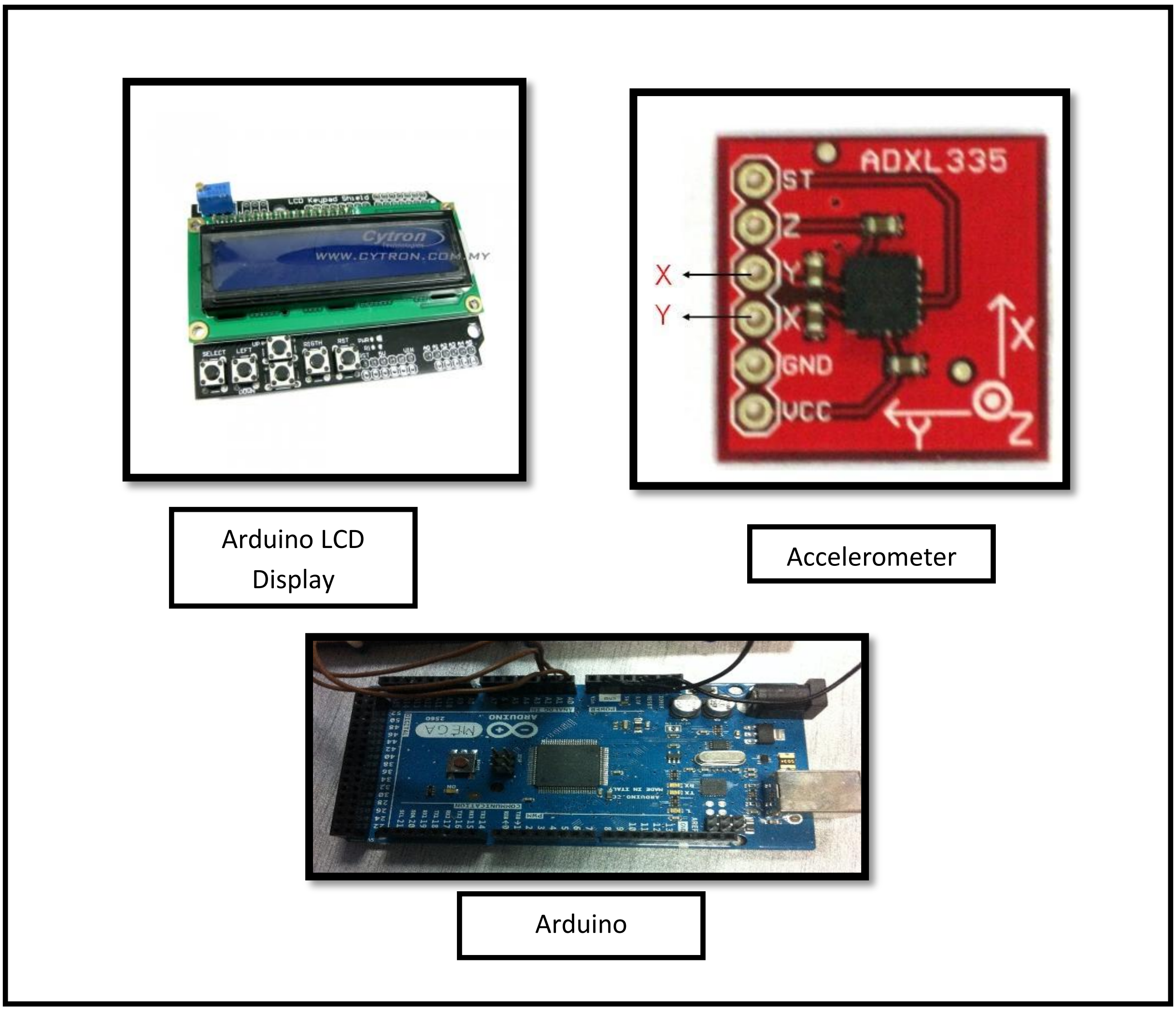


Figure 14 : Hardware

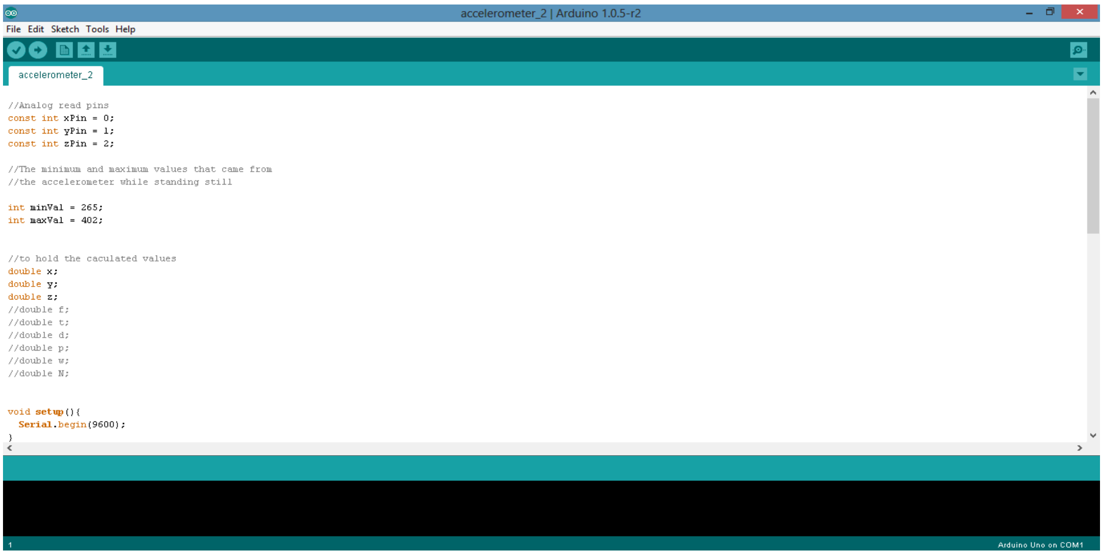


Figure 15: Arduino Snapshot

The ADXL335 accelerometer is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measure acceleration with a minimum full-scale range of ± 3g. It can measure the static acceleration of gravity in tilt sensing application. It contains a polysilicon surface-micromachined sensor [12], [13]. The sensor is built on top of silicon wafer to provide resistance against acceleration forces. The functional Block Diagram for ADXL335 is as shown in figure 16 and figure 17 shows the wiring of Accelerometer ADXL335.

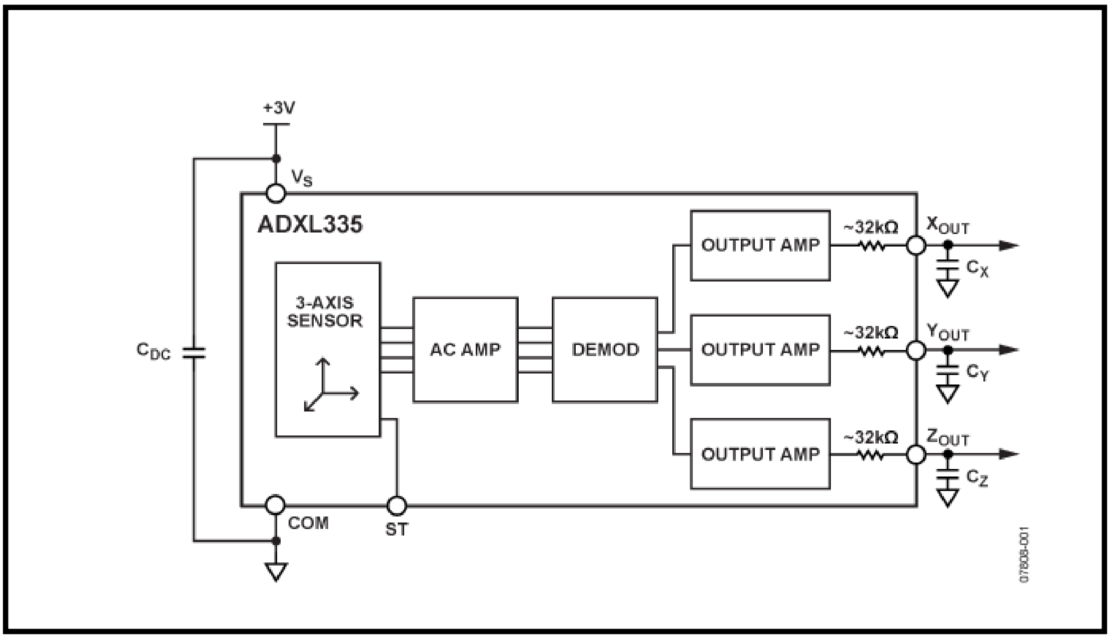


Figure 16: Block Diagram for ADXL 335 [12]

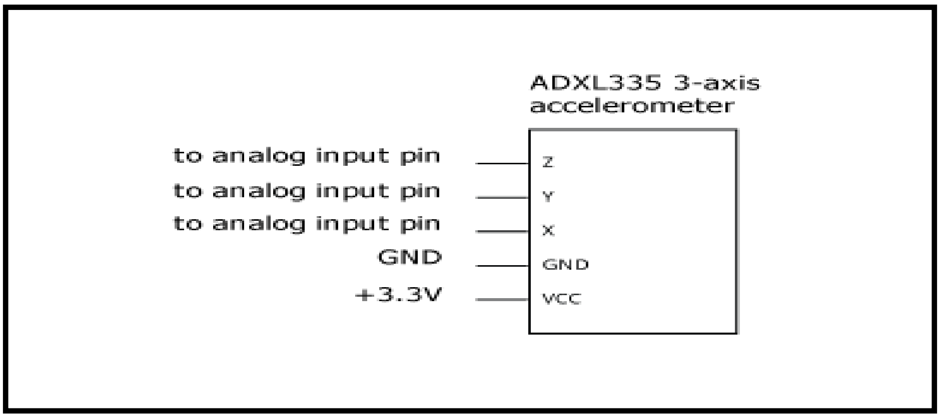


Figure 17: Wiring of Accelerometer ADXL 335 [1]

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Solar Radiation and PV Module Output Experiment

Solar Radiation Data been collected for few days to get the average daily sun hour. Besides that the PV output voltage is also collected. The data of solar radiation is collected from 9am to 5.30pm at Universiti Teknologi Petronas Solar Field Testing Facility. Figure 18 shows the experiment setup while being conducted in Solar Field Testing, UTP.

Solar radiation and PV Output Voltage are logged and saved in the data taker.

Figure 18: Setup of experiment

The solar radiation and the PV output voltage are logged and saved. The data then can be retrieved from the data taker configuration window. The data is then tabulated and graph is plotted. The experiment was carried out to find the relationship between the output of PV module and solar radiation. Experiment was repeated a few times.

The results of the experiment are as shown in the figure 10, 19 and 20. The graph of data recorded is plotted as shown in the Figure 10. The solar radiation increases from 9.00am to11.30 noon from 428W/m2 to 906W/m2. The readings continue to increases to 924W/m2 which is the peak of the day at time 12.00 noon. Then the solar radiation gradually decreases from 1pm to 5.30pm. There is a fluctuation reading throughout the day. This is mainly due to the shading effect such as cloudy, dust on PV cell and many more. Besides that, the fluctuation is due to the weather condition too.

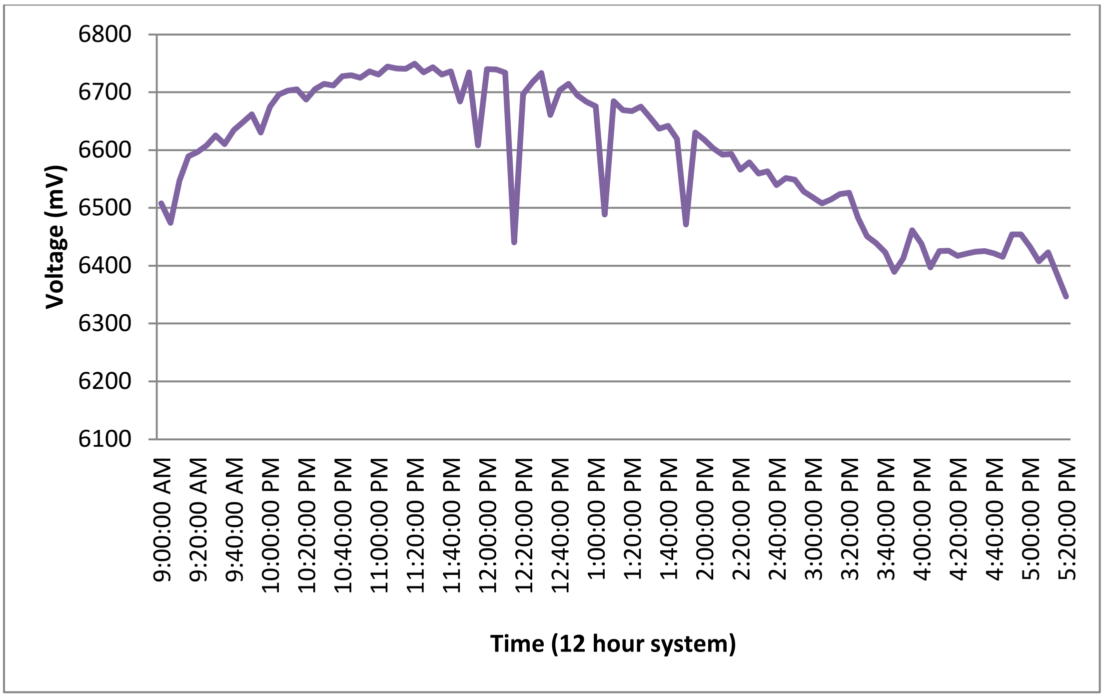


Figure 19: PV Output Voltage vs Time

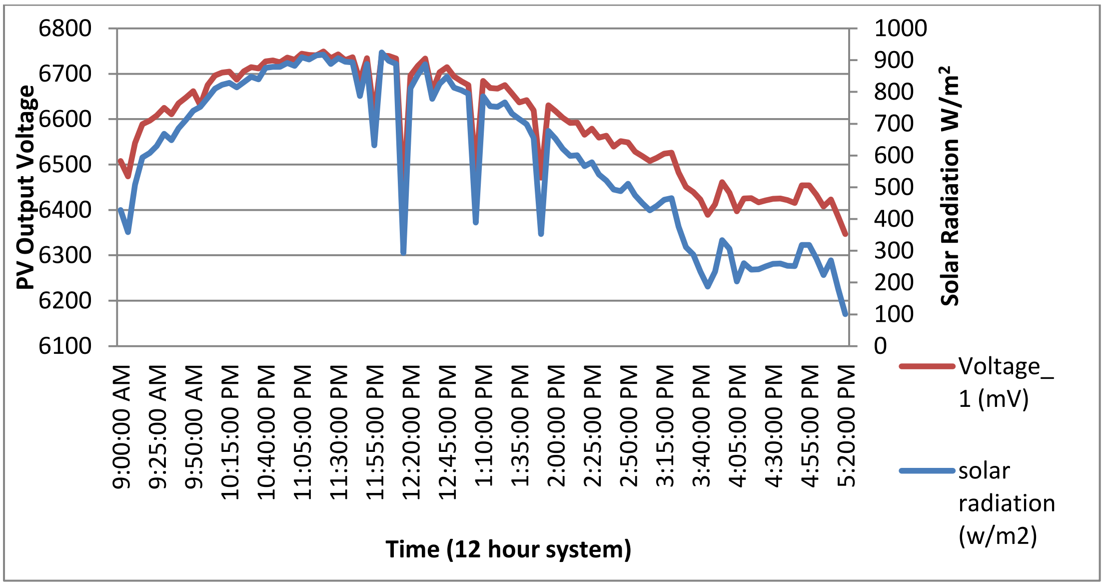


Figure 20: Solar Radiation and PV Output Voltage vs Time

Experiment to determine the relationship of solar radiation and output voltage of PV module is performed at UTP where solar radiation and output voltage is measured simultaneously. The data are analysed using multi regression analysis to obtain the relationship of solar radiation and output voltage of PV module. Figure 21 shows the relationship of solar radiation and output voltage of PV module. Equation 4.1 is the equation derived to calculate solar radiation using PV module output voltage.

$$\mathbf{y = 2.049x - 12905} \qquad (4.1)$$

In equation 4.1, y is solar radiation in W/m^2 and x is PV Output Voltage in Volt. The correlation coefficient is 0.977 which is relatively close to 1.00. Therefore equation 4.1 is adequate to fit the experimental data and can be used to calculate solar radiation.

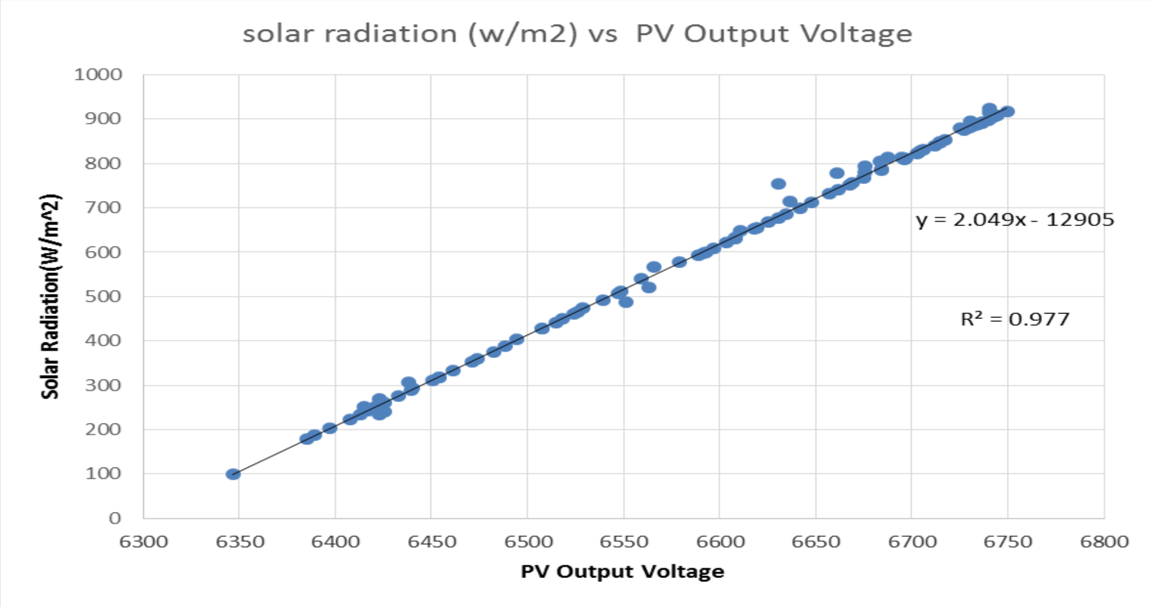
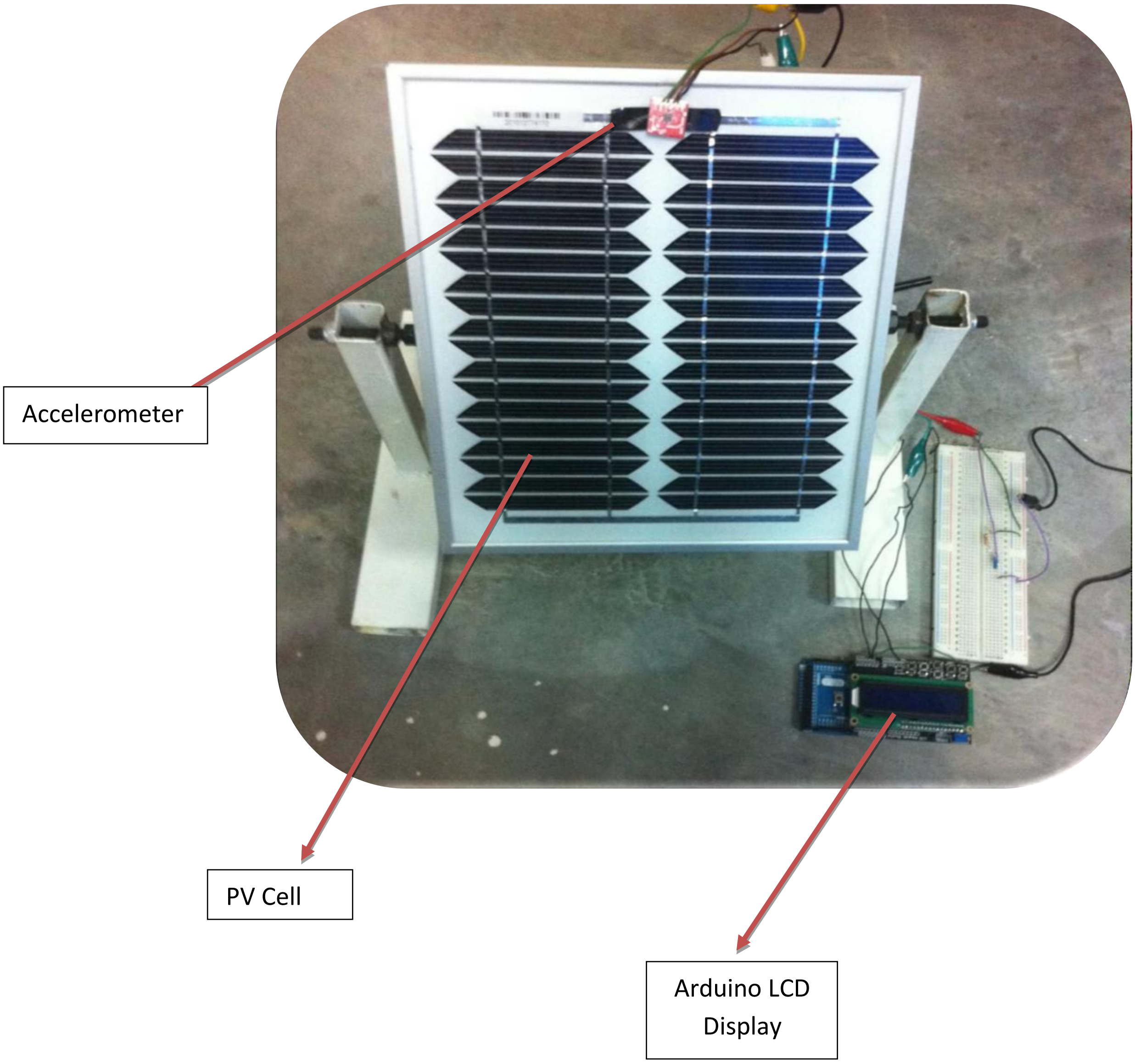


Figure 21: Relationship of solar radiation and PV Output Voltage

4.2 Solar radiation measuring device

After the equation of relationship between solar radiation and PV output voltage is obtained, an optimum angle of PV module that received highest solar radiation is obtained by using accelerometer. Solar radiation that strikes onto PV module is dependent on the angle of incident. Angle of incident is the angle between solar radiation on the surface and normal to that surface.

Figure 22 below shows the prototype of the project.



CHAPTER 5

CONCLUSION

In conclusion, this project is able to develop a mathematical model to determine the relationship between solar radiation and the PV Output Voltage. The output voltage of PV module fluctuates due to the nature of solar radiation. This is due to the local meteorological condition and the shading effect from the cloud, dust on PV cell and bird dropping. Therefore, the output voltage of PV is highly dependent on the amount of solar radiation. Therefore this project able to measure the solar radiation and be used to design the PV based solar monitoring system.

The system is also incorporate with 3-axis accelerometer which can measure optimum tilt angle of PV module that can receive high solar radiation. By this, it gives an alternative way to measure solar radiation and the cost for the monitoring system is relatively low compare to the measuring system that is already available in the market. Some of the measuring system that is available in the market is pyranometer, pyrheliometer, sunshine recorder and many more.

The recommended future work for this project would be to develop a mathematical model to determine the relationship between solar radiation and temperature. This is because temperature also is very dependent to the amount of solar radiation. Besides that, another future work for this project is to optimize the PV module sizing and battery sizing by measuring the solar radiation.

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