INVESTIGATION ON PVT PERFORMANCE UNDER LOW INTENSITY IRRADIATION

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INVESTIGATION ON PVT PERFORMANCE UNDER LOW INTENSITY IRRADIATION

by

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LIST OF ABBREVIATIONS

PV	Photovoltaic
PVT	Photovoltaic Thermal
UV	Ultraviolet
Isc	Short Circuit Current
Voc	Open Circuit Voltage
Pout	Output Power
CSP	Concentrator Solar Panel
HVAC	Heating, Ventilation and Air Conditioning
USB	Pulse Width Modulation
MHZ	Mega hertz
RAM	Random Access Memory
ICSP	In-circuit Serial Programming
DC	Direct Current
V	Voltage
A	Ampere
Vcc	Voltage at Common Collector
SD Card	Secure Digital Card
Vout	Output Voltage
Iout	Output Current
I-V	Current-Voltage
W	Watt

Siasatan Prestasi PVT Mengunakan Penyinaran Intensiti Rendah

ABSTRAK

Projek ini memberi tumpuan kepada mereka model dan mengkaji photovolta penyerab haba. Photovalta panel solar dengan penyerab haba matahari dan tanpa penyerab haba akan dilakukan dan dianalisis. Projek ini menggunakan air sebagai bahan penyerab haba daripada Photovalta panel solar. Pengudaraan panel solar dan air penyerab haba panel solar boleh kecekapan panel yang tinggi. Objektif pertama projek ini adalah untuk membina model penyerab haba panel solar dengan megunakan air dan menganalisis model. Objektif kedua projek ini adalah untuk mengkaji sama ada panel solar dengan penyerab haba mempunyai kecekapan yang tinggi daripada panel solar tanpa penyerab haba atau tidak. Pengukuran data daripada sistem Photovolata dengan penyerab dan tanpa penyerab mengunakan Arduino. Semua parameter elektrik akan disimpan pada kad SD mikro bagi setiap 5 minit dengan menggunakan Arduino. Data ujian panel solar ini bertujuan untuk melihat ciri-ciri I-V panel solar untuk kedua-dua panel dengan penyerab dan panel solar tanpa penyerab haba. Ujikaji dijalankan dalam masa 5 jam untuk mendapatkan nilai arus elektrik, voltan dan kuasa maksimum kedua-dua syarat jenis panel solar. Kedua-dua prestasi panel solar dengan penyerab haba dan tanpa penyerab haba bandingkan dan dikaji. Hasil daripada ciri-ciri I-V menunjukan peningkatan voltan litar banyak 4% dan arus elektrik bergurangan sebanyak 2%. Hasil daripada ujikaji menunjukkan peningkatan kuasa elektrik sebanyak 6% dan suhu panel solar berkurangan sebanyak 6% apabila mengunakan penyerab haba panel solar.

Investigation on PVT Performance Under

Low Intensity Irradiation

ABSTRACT

This project is focused on modeling and analyzing photovoltaic thermal water collector. PV solar panel with the solar thermal collector and without thermal collector will be presented and analyzed. This project used water as the coolant of the PV solar panel. Naturally ventilated panels and water cooled panels can provide high efficiency. The first objective of this project is to build PVT water collector and analyzing the model. The second objective of the project is to investigate whether a PV solar panel with thermal has high output than PV solar panel without or not. Microcontroller data acquisition was built to measure the data from the PVT system. All the electrical parameter will be saved on micro SD card for every 5 minutes using data logger developed using Arduino. The data Solar panel testing is conducted to observe the I-V characteristics of solar panel for both PV with and without a thermal collector. System testing is conducted within 5 hours to obtain output current, output voltage and maximum output power of both conditions of PV solar panel. Both performance of PV solar panel with and without thermal collector is compare analyzed. The result from I-V characteristics shown open circuit voltage increase about 4% and short circuit decrease about 2%. The result from system testing shown output power increase about 6% and temperature of solar panel decrease about 6% when water thermal collector have been used as a cooling system.

CHAPTER 1

INTRODUCTION

1.1 Background

Renewable energy is energy that derived from the natural processes and they can be replenished at a faster rate than they are consumed. There is lot type of renewable energy type in this world such as solar energy, wind energy, wave energy, biomass energy, and hydropower. Most of the sources of renewable energy are fluctuate and not constant depending on weather, day and seasons. Malaysia is gifted with renewable energy resources such as hydro, wind, solar, geothermal and tidal wave but most of these renewable energy resources are not fully utilized [1].

Solar energy is energy which is created from the sunlight or heat from the sun. The utilization of solar energy has traditionally been divided into two fields it is heat energy and electrical energy. Solar thermal utilization of solar radiation to provide useful heating such as passive solar heating of houses and solar water heating. Malaysia has abundant sunshine with the average daily solar insolation of 5.5 kW/ m2, which is equivalent to 15 MJ/ m2 [2].

The power energy and current that produces from the panel depends on temperature and irradiance of sunlight. The temperature and UV light are not constant from time to time. The use of concentrator can increase the panel temperature significantly. The operating temperature is increased because a large part of the solar radiation is not converted to electrical but is absorbed by the panel as heat. When the temperature of the panel increase the current and power that produces from the panel is decreased. The overall efficiency of the system will decrease due to the high temperature of the panel. The power output of solar panel will be reduced by between 0.25% (amorphous cells) and 0.5% (most crystalline cells) for each ◦C of temperature rise[3].

PV panel that exposes under sunlight will gain electric energy with photons and at the same time it produces excessive heat energy. This project is conducted to collect the excessive heat energy and remove it. PVT collector is a hybrid collector that generates electric and heat energy simultaneously. There is two type of thermal collector that usually used with a solar panel to absorb extra heat it is a liquid or air collector. The thermal collector acts as a cooler for the solar panel.

Propose of work is to create thermal collector to extracted heat from the solar panel thus increasing the overall efficiency of the system. The efficiency solar panel with the thermal collector and without thermal collector is difference especially using the concentrated solar panel. Solar panel that uses the mirror as a concentrator will absorb more heat energy than not using concentrator. The performance of solar panel with the thermal collector and without thermal collector will be analyzed based on the data that is collected.

1.2 Problem Statement

Solar panel concentrator is used to generate more electrical energy and output power of the solar module by increase the intensity of sunlight. The performance of PV solar panel are is depend on the temperature of solar cells. When using solar panel concentrator the temperature of the solar cell will increase rapidly and leads to a reduction in open circuit voltage, output power, and efficiency of the solar panel. Therefore, to overcome these effect and to maintain the operating temperature of PV solar panel, it is necessary to remove heat from the PV solar panel by the cooling method. Active cooling techniques are used in this project to remove heat in order enhance the performance of PV solar panel.

1.3 Objective

1) To design a photovoltaic thermal heat collector for the low irradiation concentrator photovoltaic system.
2) To investigate active cooling for enhancing low irradiation solar concentrator operation in Malaysian climate.

1.4 Project Scope

Sun intensity and solar radiation are the difference for each place at Malaysia. This project has been conducted in campus Universiti Sains Malaysia at Nibong Tebal.

The experiment has been conducted in April and May. The time of experiment at 10.00am to 3.00pm. The instantaneous global solar radiation received on the surface of the earth in Malaysia on a clear sky day around noon time can be up to 980 W/m2[4].

Poly-crystalline 50 Watt of the solar panel was used in this project to test its performance. Thermal heat collector for low irradiation concentrator will be designed and developed. PVT water thermal collector was used in this project as a cooling unit to reduce the temperature of the solar cell. Water in the thermal collector will be circular in close loop system to transfer heat of solar panel from solar cell to heat storage. This technique is known as the active cooling system of the solar panel. This research is carried out by using Data logger and hardware setup.

The performance of the PVT will be analyzed based on the value of voltage, current, power, and temperature of the solar panel that record by Data logger. The performance of solar module with and without thermal collector will be analyzed. The sensor will be used to measure all the parameter and all the data will be saved on data logger system develop by using Arduino Uno microcontroller.

1.5 Project Outline

This thesis has five main chapters that describe all information, data, and details on this project. Chapter 1 is an introduction that covers the background of the project, problem statement, objective, and project scope. This chapter provides the basic knowledge on this project.

Chapter 2 is an overview of the solar energy and background to the photovoltaic and solar thermal fields. Many research in the field of combined photovoltaic-thermal collectors using water or air as the working fluid. A review of concentrator PV which is used Fresnel lenses or mirror. This chapter also explained about the factor that affects the efficiency of the solar panel.

Chapter 3 explains the methodology that is implemented on this projects. This chapter describes all the method implemented on this project. The methodology explained about hardware development, designing thermal heat collector, selection of components, a current sensor, a voltage sensor, and calculation.

Chapter 4 contains a detailed discussion of individual components of the thermal heat collector, solar panel temperature, concentrator, and output power. This chapter represents the result and discussion of the project. The result has been represented in the graphical method. Analyzing the performance of thermal heat collector are discussed in this chapter. Chapter 5 represent the conclusion of the whole projects and recommendation for the future to improve this work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Solar PV system is a conversion of solar energy directly into electrical energy. The system has no moving part and not going through the thermal-mechanical link. Solar PV system is reliable, pollution-free, quiet and compatible with almost all environment. A life span of PV system is expected of 20 years or more.

The basic element of PV system is a solar cell. The solar cell is a bulk silicon cell where the bulk material is the P-type silicon. A thin layer of N-type silicon is formed on the top surface. Solar PV module is a building block of a PV system and it has interconnection of a number of cells that has same characteristics. Solar PV panel is a several solar modules that is connected in series or parallel or both and encapsulated in a frame.

Nowadays, solar energy has used for generating electrical, providing light and heating water for domestic or industrial use. The limitation of solar energy is that solar energy cannot be used at night and the amount of sunlight that received on Earth depends on location. The key technologies of the PV system include two sides it is the control strategy and the power electronics technology[5]. The research and development in PV system are needed to make PV system has high efficiency and cost effective.

2.2 The Sun

The surface temperature of the sun is around 6000 K and the center of the sun is very much hotter, at around 20,000,000 K. The radiation emitted from the sun comes from different temperatures, which emit and absorb radiation of varying wavelengths. The radiated energy that reaches the earth from the sun has different intensities at different wavelengths. Figure 2.1 compares the energy distribution of radiation at the mean earth-sun distance with that actually reaching the earth and on the ground[6].

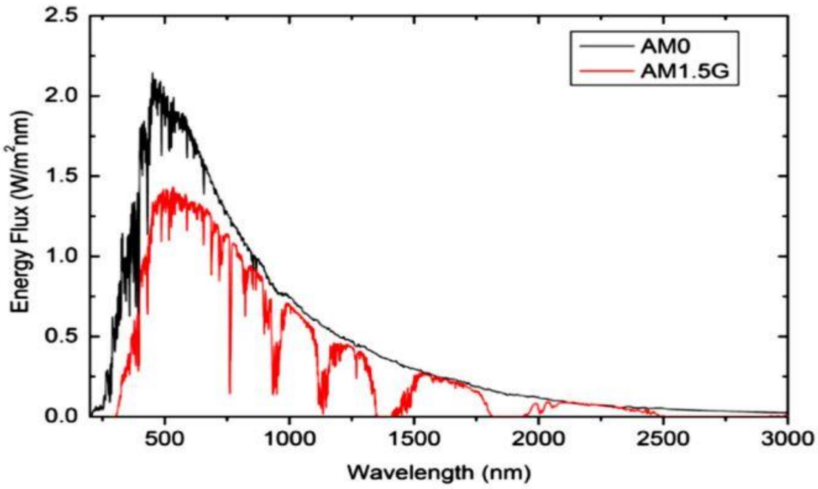

Figure 2.1: AM0 and AM1.5 solar irradiance spectra [6]

Air mass (AM) refers to the path length of sunlight through the atmosphere and is approximated by 1/cos(θ), where the sun is at an angle to vertical[6]. Three common irradiance spectra have been applying by many researchers to provide standard conditions to measure solar cells. The AM0 intensity is the first common reference and indicates the amount of radiation that passes through no atmosphere. Approximately 40% of the AM0 intensity is lost from absorption by the atmosphere and scattering[7]. AM1 is a second reference spectrum and represents the solar radiation that would be received if the sunlight were directly overhead. AM1.5 is the third and most common reference spectrum, corresponding to a solar incidence angle of 48.2° relatives to the surface normal and produces one solar illumination (1000 W/m2) as a mean irradiance[8].

For some wavelengths, atmospheric gasses such as ozone, O2, H2O, and CO2 strongly absorbs light and this causes the absorption bands apparent in Figure 2.1. By the time light reaches the earth, the total energy density is about 970 W.m-2 for Air Mass 1.5. The value of irradiance 1000 W.m-2 has become the standard for photovoltaic work[7].

2.3 Photovoltaic

A photovoltaic solar cell is a semiconductor device, which converts sunlight into direct-current electricity. Over 90% of the world's photovoltaic market is for crystalline silicon solar cells [9]. Figure 2.2 shows that the light which has a wavelength of less than 1200 nm has enough energy to break a bond in the silicon, creating a free electron and a free hole.

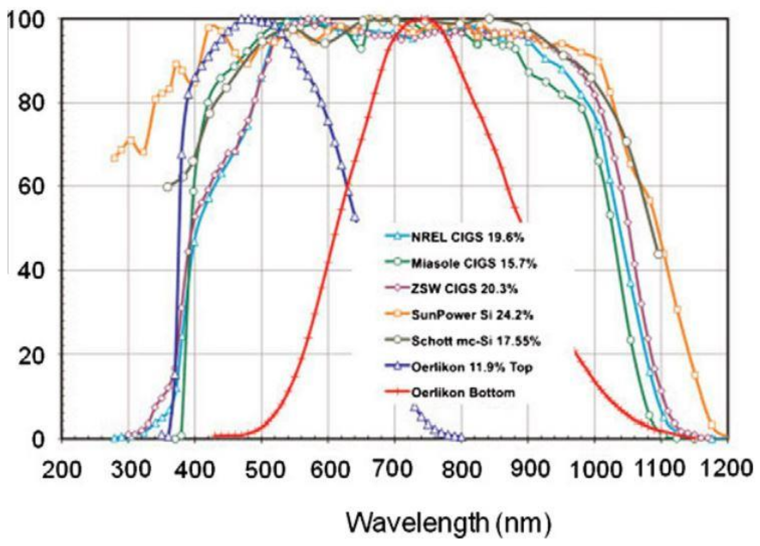

Figure 2.2 External quantum efficiency for many types of the solar cell[10].

The External Quantum Efficiency (EQE) of a solar cell is a measure of the probability that photons incident on a solar cell that contributes to the electrical current[10].In Figure 2.2 shows that the light with a wavelength between 400nm and 1200nm has been creating electrons that contribute to the cell current. At wavelengths lees than 400 nm, many of the photons are lost due to increased reflection from the top surface of the solar panel and absorption in the anti-reflection coating itself. At wavelengths greater than 1100 nm, light is only very weakly absorbed by silicon and does not contribute to generating electrical current. This is because silicon requires photons with energy greater than 1.1 eV, corresponding to wavelengths less than 1100 nm, to lift an electron from the valence band of the silicon atom to the conduction band where it can move about freely[10].

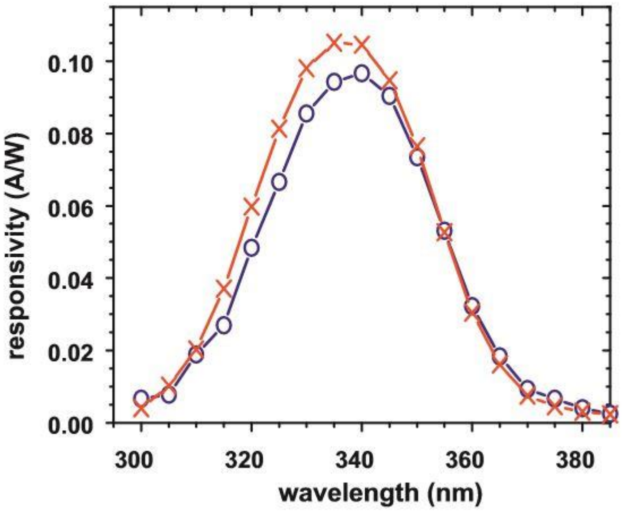

Figure 2.3: Spectral responsivity of the solar cell structure with single layer spectrum(x) and double layer spectrum structure (O) [11]

The spectral responsivity of a solar cell is a measure of how many Amps are generated per Watt of incident light. The spectral responsivity drops off for shorter wavelengths because the incoming photons have more energy to create a free electron. The excess energy is dissipated as heat. A high-quality silicon solar cell with close to ideal quantum efficiency will always have the bulk of the sun's energy converted to heat[11]. This is one of the motivations to study PVT collectors – to significantly increase the efficiency of solar energy. The ideal I-V characteristics of such device are given by[12]

$$I = I_o\left(exp\left(\frac{qV}{nkT}\right) - 1\right) - I_{sc} \tag{2.1}$$

Where Io,q,n,k and T are saturation current, elementary charge, diode ideality factor, Boltzmann constant and absolute temperature respectively. For a silicon solar cell, when the forward bias across the solar cell rises to a value of around 0.6 to 0.7 V, a large forward current begins to flow, opposing the reverse current due to the illumination[12]. There is a point on the I-V curve where the product of the current Imp and voltage Vmp is maximum, called the maximum power point. The fill factor of a solar cell is defined as follows[13]

$$FF = \frac{I_m - V_m}{I_L - V_{oc}} \quad (2.2)$$

Typical fill factors are around 70% to 80%. The temperature of a PV solar panel depends very much on the configuration of the installation[13]. The efficiency of a solar cell falls as the temperature increases, mainly due to a reduction in open circuit voltage, typically around 2.0 to 2.4 mV/°C and overall solar cell efficiency declines with the temperature at a rate around 0.3 to 0.4 %/°C.

2.4 Working principle of solar cell

The photovoltaic effect is a process of a solar cell convert light energy to electricity. When the solar cell is exposed to sunlight some of the photons of the light ray will be absorbed by the semiconductor crystal and break apart electron-hole resulting free electrons. These electrons and holes move through the crystal lattice. The electron created in the p-region reaches the p-n junction, it will cross to the n-region and accumulate with other electrons[14]. The same process happens in reverse for the holes created in the n-region, and the effect is a voltage build up across the p-n junction. Power can be extracted from the solar cell by connecting the p-region to the n-region to an external circuit.

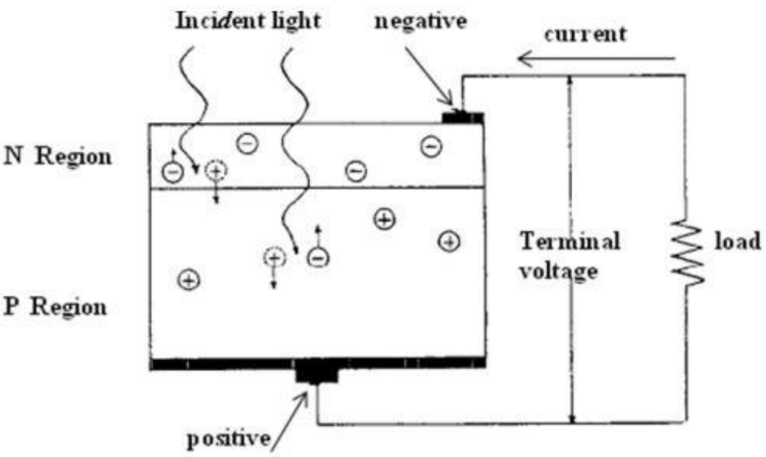

Figure 2.4: Schematic diagram showing operation of silicon solar cell[14]

2.5 Concentrator solar cells

The efficiency of the solar cell increased by concentrating photovoltaic and the cost of photovoltaic decrease by concentrating. The traditional solar cells used for concentration were III–V multi-junction solar cells, their costs were high although they had high efficiency, thus people tried to use cheaper silicon solar cells for concentration to decrease the costs further[15]. In this work, six kinds of silicon solar cells with different structures used for concentration. Six kinds of silicon solar cell that investigate for concentration is front and back contact cell, back contact cell, vertical junction cell, micro cell, silicon-based hetero-junction cell and silicon-based multi-junction cell. The result from the research shown that the back contact cell and the multi-junction cell have good potential in low, middle, high and very high concentrator photovoltaic[15].

Silicon solar cells that used for concentrator systems have low internal series resistance and high current density due to concentrated sun's light. Series resistance affects the fill factor of the cell. Series resistance is made up of a contact resistance between the metal and semiconductor[16]. The other form of resistance is known as shunt resistance. This is caused by defects in the p-n junction and leaking currents along the edges of the solar cell. Shunt resistance losses are usually negligible at high concentration ratios[17]. These resistances can be modeled in an equivalent circuit modeling a solar cell, as shown in the Figure2.5. The circuit is comprised of a diode, a constant current generator, a shunt resistor and an internal series resistance.

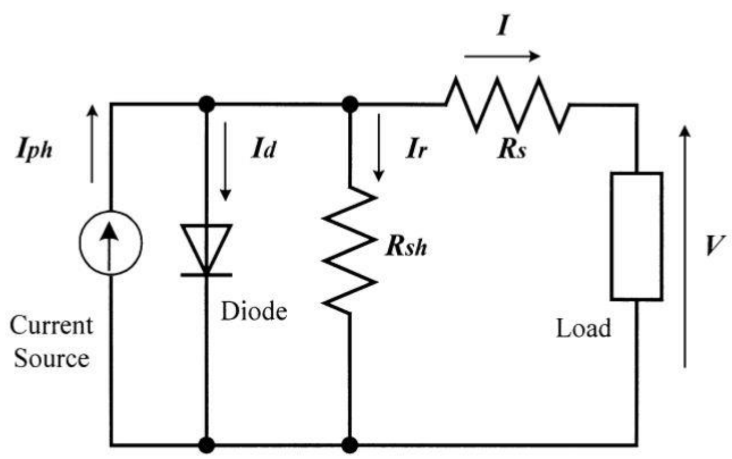

Figure 2.5: A solar cell equivalent circuit during normal operation[18]

Based on the equivalent circuit in gigure2.5, a relationship between current I and voltage V can be derived[19]:

$$I = I_{ph} - I_d \left[\exp\left(\frac{V+IR_s}{mV}\right) - 1\right] - \frac{V+IR_s}{R_{sh}} \quad (2.3)$$

The most commonly material used for making concentrator solar cell is silicon than other material. A concentrator photovoltaic system used the inexpensive solar concentrator such as Fresnel lens and dish-type mirror to concentrated sunlight into a small size of the multi-junction solar cell. The efficiency of the multi-junction solar cell is excess 35% by using concentrator photovoltaic system[20]. Multijunction cells achieve high overall efficiencies by having two or more cells stacked together and each solar cell has designed for a particular wavelength range within the solar spectrum. The peak efficiency of the multi-junction solar cell is 37.4% at 200x concentration, achieved by Takamoto, Masafumi and Kenji at the year 2003[20]. The production cost of multijunction solar cell material is higher than silicon solar cell. However, to reduces total cost of concentrator system it is necessary to decrease the size of the multi-junction solar cell[12].

2.6 Type of Solar Cell

A solar cell made up from a semiconductor material such as silicon or germanium. The solar cell is also known as a photovoltaic cell or photoelectric cell. An atom of silicon has 14 electrons and its outer shell has 4 electrons. The semiconductor of solar cell has two difference layer that is combined together. A P-type layer of the semiconductor has doped with the trivalent element and has an excess amount of hole. N-type layer of the semiconductor has doped with the pentavalent element and has an excess amount of electron.

2.6.1 Mono-crystalline photovoltaic cell

The mono-crystalline is produced from pure silicon or single crystal ingot. The Mono-crystalline silicon is manufactured from pure and defect-free single crystal ingot. This type of solar cell has high efficiency, dependable and most commonly used. The monocrystalline ingot is manufactured by Czochralski Process. A silicon seed crystal is dipped into melted Poly-crystalline silicon to form a cylindrical ingot of very pure silicon. These process also remove impurity and the silicon through a heated zone. At the specific point, the silicon is deemed pure, and the impurities which end up at the ingot are removed.

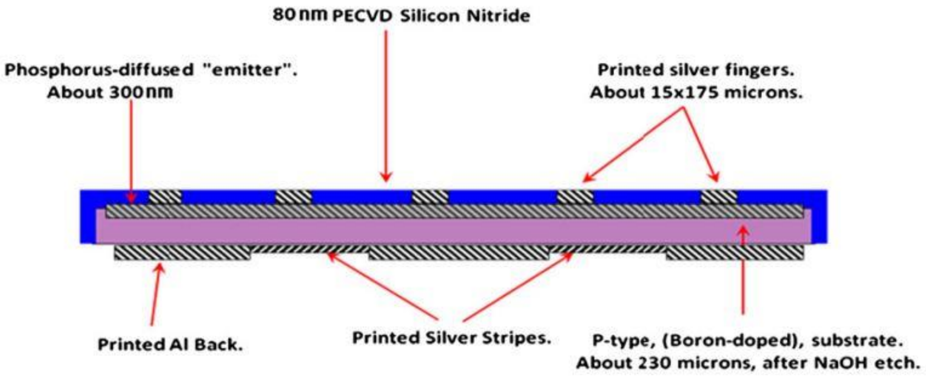

Figure 2.6: Mono-crystalline solar cell structure [21]

2.6.2 Poly-crystalline photovoltaic cell

Poly-crystalline or multi-crystalline cells are the most common used because this type of material is not expensive. In the Poly-crystalline silicon cell, liquid silicon is used as raw material. The Poly-crystalline growth process was created by solidification process of molten silicon. The ingot material contains various crystalline sizes that can be seen on its surface. The efficiency of solar cell made from poly-crystalline is slightly less than a mono-crystalline silicon solar cell. The solar cell's efficiency is up to 17.37% and solar module efficiency is up to 14.62%[9]. This solar panel has low voltage temperature coefficient to ensure it has a high-temperature operation.

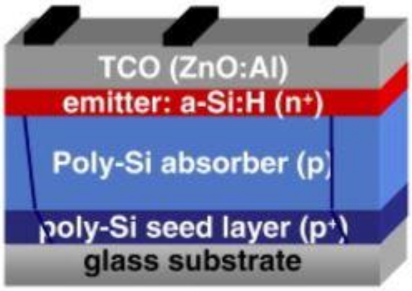

Figure 2.7: Cell Structure of Poly crystalline [22]

2.6.3 Thin film technology

The thin-film crystalline solar cell consists of layers about 10um thick as compare with 200-300um layers for crystalline silicon cells. Thin film technology depends on the type of material used to dope the substrate such as metal, polymers or glass. The advantages of this thin film technology are a low-cost substrate, easy fabrication process, and flexible PV module. The disadvantages are not very stable and also low operation lifetime compares to silicon type solar cells. An example of thin cells is cadmium telluride, copper indium gallium and amorphous silicon.

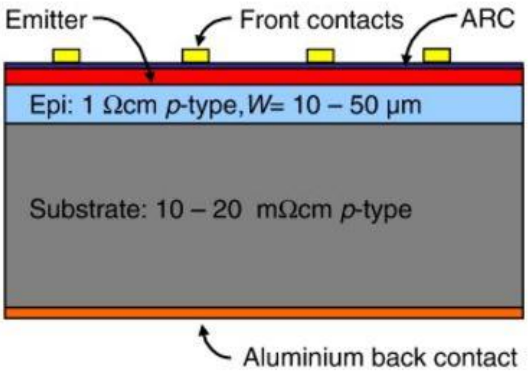

Figure 2.8: Structure of thin film solar cell[23]

2.6.4 Amorphous silicon

Amorphous silicon is obtained by depositing silicon thin film on the substrate glass plate and with no definite arrangement of atoms. The layer thickness amount to less than 1um. The efficiency of this solar cell is less than mono-crystalline and polycrystalline silicon. This solar cell is used mainly in low power equipment such as calculator, watches or fan. The advantages of this solar cell are less silicon and more effective in a hotter climate. The disadvantages are low efficiency and operating lifetime.

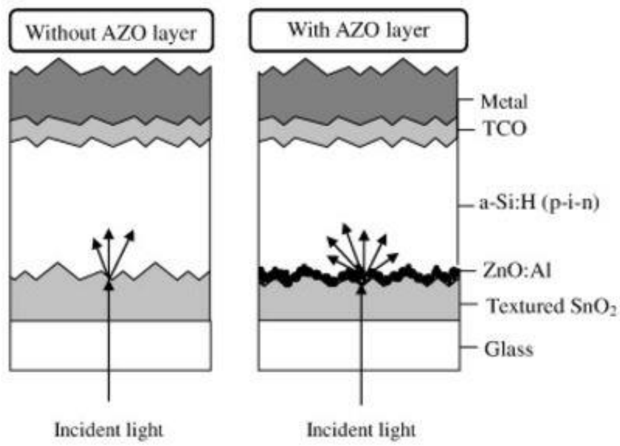

Figure 2.9: Light scattering mechanism of the amorphous silicon solar cells without AZO (left) and with AZO (right) thin film[24]

2.7 Solar panel concentrators

The concentrator is a system to concentrate a large area of sunlight to a small area of the solar panel. The solar concentrator is used to increase the intensity of the sunlight. When the intensity of the sunlight increase the photovoltaic system will generate more output electricity and become more efficiencies. This is because output power of the solar cell depends on the intensity of light that exposed to the solar panel. The advantage of the solar concentrator is reducing the number of solar panels used and will reduce the cost of the photovoltaic system.

Three types of concentrator PV is low concentration PV, medium concentrator PV, and high concentration PV. Low concentrator PV have a solar concentration of 1-10 suns. The medium concentration has 10-100 suns and the PV system need two axes solar tracking and cooling system to archive highly efficiency. For concentrating PV it needs concentrating optics to concentrate sunlight to intensities of 100 suns or more[25].

Concentrator photovoltaic system can be divided into two main categories it is Fresnel lens and silvered glass mirror. The two type of concentrator photovoltaic can be either point focus or linear focus concentrator. All the concentrator system with intensity more than 4x suns and use direct radiation from the sunlight.

2.7.1 Fresnel lens

Fresnel lenses can be designed with a near uniform radiation flux profile on the cells. However, mirrors are usually cheaper and allow for single axis tracking and therefore simpler and cheaper mounting. The concentrating photovoltaic thermal system with transmissive Fresnel solar concentrator has been designed by Rui Wang and Hongfei[26]. Main parameters are tested such as the temperature distribution of receiver, electric energy, and thermal energy. The test results in clear weather show that maximum electric generating efficiency is about 18% at noon, the maximum heat receiving a rate of cooling water is about 45%. At noon time (11:00–13:00), the total efficiency of thermal and electricity can reach more than 55%.

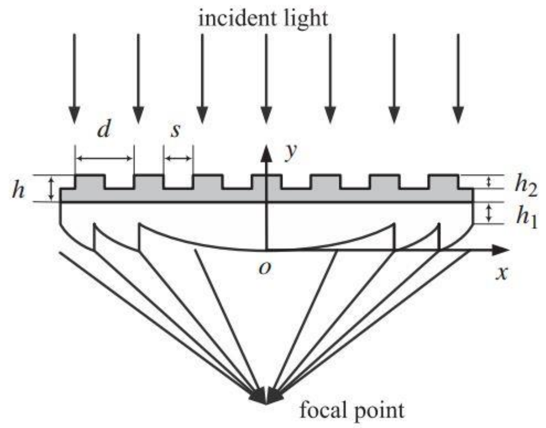

Figure 2.10: Schematic diagram of imaging Fresnel lens[27]

Concentrated photovoltaic is a major application and the highest efficiency based on imaging Fresnel lens and non-imaging Fresnel lens are reported as over 30% and 31.5 ± 1.7%, respectively. The imaging Fresnel lens refracts light from an object and forms an image in the focal. Thus, the only way to successfully utilize imaging systems is to employ accurate tracking. Additionally, imaging Fresnel lens systems create a more or less defined focal area, which leads to "hot spots" problem on oversized receivers[28].

For non-imaging Fresnel lens solar concentration systems which always adopt convex, dome-shaped or two-stage lenses to realize low, medium and high concentration. Non-imaging Fresnel lens concentrators are thought to be very competitive solar collectors because of their high optical efficiency, light-weight and cost effectiveness. With the lower manufacturing complexity, non-imaging Fresnel lens solar concentration systems are expected to extensive using in the field of commercial solar power generation[29].

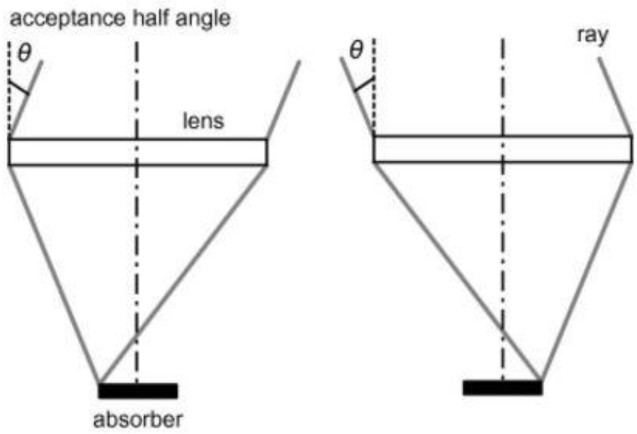

Figure 2.11: Principle of designing non-imaging Fresnel lens with acceptance half angle[30].

2.7.2 Silvered glass mirror

A silvered glass mirror is an object that reflects light. Silvered is a process convert a plane glass sheet to a mirror. The silvered process deposits a coating of pure silver on a glass sheet or a glass plate. The commonly used reflectors in CSP applications are silvered glass mirrors with a glass thickness of 1 to 4 mm. Thick glass mirrors typically have a thickness of 4 mm offering sufficient mechanical strength against wind loads. Thin glass mirrors, usually of 1 mm glass thickness, require a backing structure to prevent mirror breakage and to provide the concentrating shape[31].

Tina and Scandura have discussed the efficiencies of the PV systems are calculated and measured to evaluate the cost-effectiveness of a low-concentration system V shape mirror and single-axis tracking[32] The schematic diagram of the V-through concentrator is shown in figure 2.12.

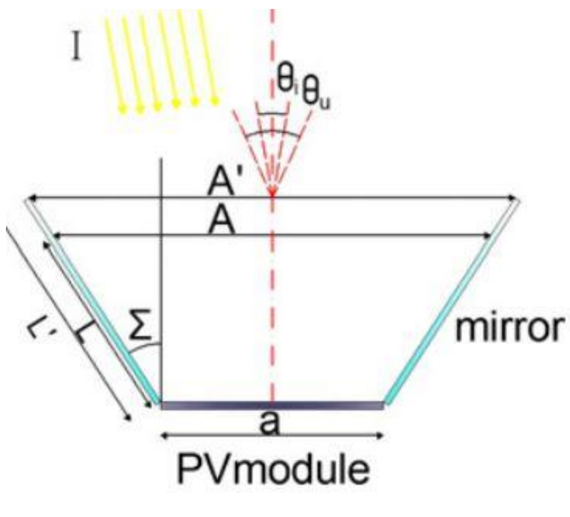

Figure 2.12: Schematic diagram of V-through concentrator using a flat mirror.

For low concentrations, the most widely used device is the V-trough concentrator, which consists of flat mirrors on either side of the photovoltaic module. This device can achieve a geometric concentration of greater than 2x suns. The result from the research shown that the low-concentration system capital's cost includes PV array and inverter, which is approximately 25% higher than that of the one-axis tracker PV system which includes the operation costs, which are supposed to be higher.

2.8 Factors that affects the efficiency of solar panel

The solar panel efficiency is the percentage of sunlight hitting a panel gets turned into electricity. The typical solar panel efficiency rating is around 14-18% efficient. Besides solar panels efficiency and size, there are other factors that affect the power of solar panels. Living in Arizona will get more solar radiation than someone who lives in the Midwest. Solar energy output is also affected by weather, seasonal variations, and the angle of the sun to the solar panel changes with the time of day and temperature of the solar panel also contribute to less effectiveness of the sunlight collection.

2.8.1 Temperature

The high temperature of the solar panel will reduce the efficiency of the solar panel. The hotter the cell material is, the more resistance there is and the slower the electrons can move through it. This means the output power of solar panel goes down because not as many electrons can get through the circuit. The high-quality panel is designed to maintain performance in high temperature. Lower quality panels lose efficiency and produce less energy. High temperature causes a drop in voltage and a drop in power. If the temperature increase, the electron's 'rest temperature' is increasing. The photons transfer less energy to excite the electron. As a result, the PV system produces less energy and low efficiency.

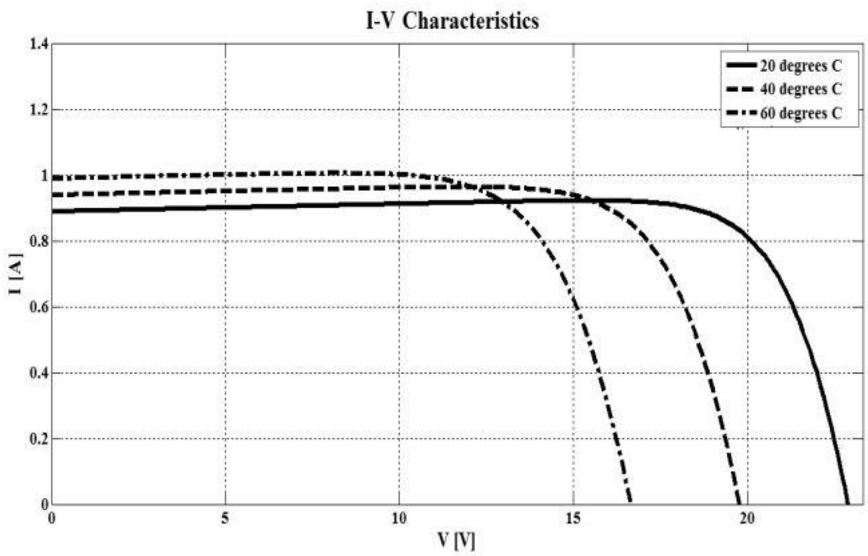

Figure 2.13: I-V characteristic for various temperature[33]

Figure 2.13 show the I-V characteristics of PV solar panel for a different level of temperature. Short circuit current is slightly decreased and open circuit voltage is increased when the temperature of solar panel decrease have been shown in I-V characteristic. The relationship of this I-V characteristic when an open circuit is shown in the figure below.

$$V_{oc} = \frac{\alpha kT}{q} \ln\left(\frac{I_{ph}}{I_o} + 1\right) \tag{2.4}$$

Io is saturation current that composed as a diode. The saturation current depends on the temperature. When the temperature is increased, saturation current will increase and open circuit voltage will decrease.

2.8.2 Sun intensity

Irradiance is an amount of light intensity that reach the solar cell. Changing the light intensity on a solar cell make change all solar cell parameter such as Ioc, Voc, the fill factor and the efficiency. The higher the light intensity, the more electrical energy produced. High radiation of sunlight will increase the temperature of the solar panel.

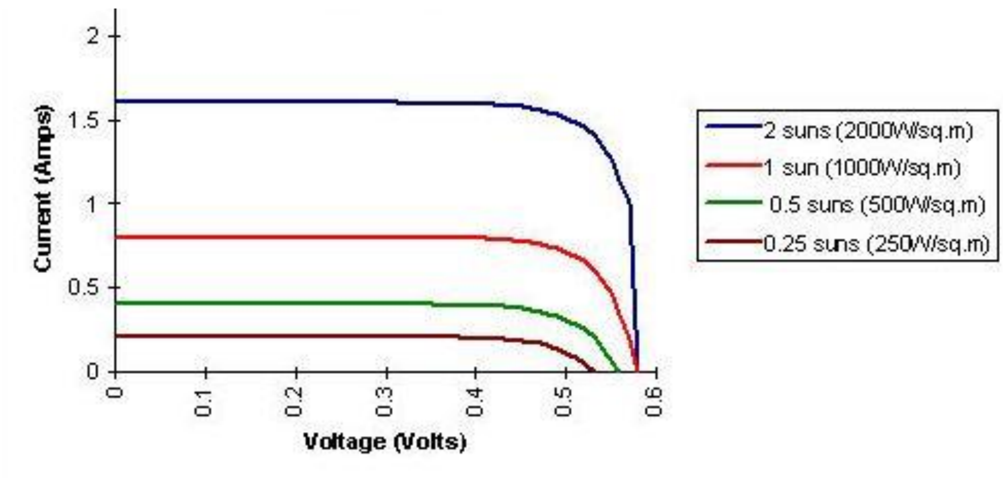

Figure 2.14: Current and voltage curve of a solar panel under various suns intensity[34]

2.9 Combined photovoltaic – thermal

The combined photovoltaic thermal (PVT) collector is solar energy that produced both electricity from the solar cells and heat energy. In general PVT collector is refer to a system with active heat collection through heat transfer fluid such as air, water or both to reduces the temperature of the solar panel. PVT system is not a new concept because the system is progressing far from the laboratories of research institution around the world. The main reason for combined PVT system over separate PV and thermal system are expected cost reduction due to combined production, installation and more efficient utilization of the variable sunlight[35].

2.9.1 Liquid collector

In the work by Rohit Tripathi and G.N.Tiwari, two cases were considered to study the annual behavior of present system cases. The first case is the fixed position of solar panel and second case is manual maximum power point tracking technique. Consecutive days are selected for taking observation for both cases in each month throughout years. In this experiment, the reflectors are made of stainless steel to focus more sunlight on the solar panel. Closed loop system of thermal water collector was set up to produce with forced and for higher storage water temperature[36].

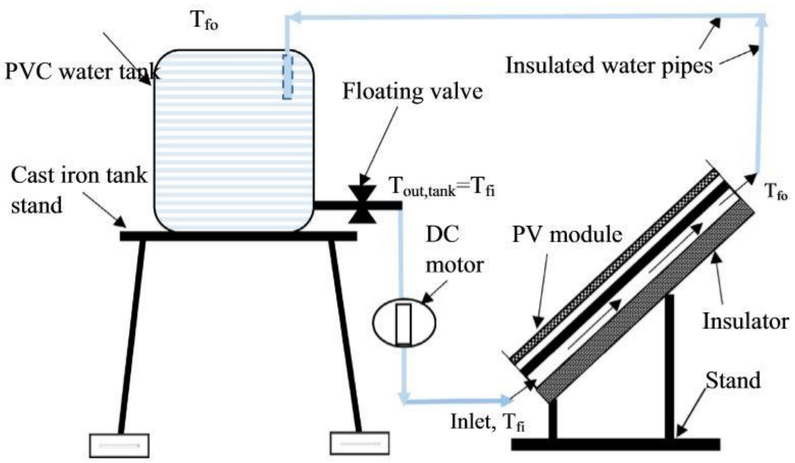

Figure 2.15: Experimental setup for fully covered photovoltaic thermal-compound parabolic concentrator collector in forced mode.

In Hongbing, Saffa and Yu Fu's work, refrigerant was employed to cool the PV modules. By using low evaporating temperature, it was expected to achieve the better cooling effect and electrical performance of the PV modules than using air and water working fluids. Three testing modes were proposed to investigate the effect of solar radiation, condenser water flow rate and condenser water supply temperature on energy performance. The electrical efficiency of PV panel with thermal collector was improved by up to 1.9% based on a reference PV efficiency of 3.9%, compared with that without a thermal collector. In their finding, the condenser water supply temperature and water flow rate had little effect on the electrical performance[37].

The basic water-cooled is used conductive metal piping or plate attaches to the back of PV module. The type of fluid that commonly used is water, glycol or mineral oil. The fluid absorbs the heat of the solar panel through metal and carries the heat to another place. Water type of PVT is more effective than air type. There is two type of absorber sheet and tube absorber and fully wetted absorber. Most of the water-cooled PVT panels on the market today are based on the assumption of cooling the PV cells removing heat through a circuit in which the heat transfer fluid circulates [38].

2.9.2 Air collector

The basic air-cooled design uses a hollow, conductive metal housing to mount the photovoltaic (PV) panels. Heat is radiated from the panels into the enclosed space, where the air is either circulated into a building HVAC system to recapture heat energy or rises and is vented from the top of the structure. While energy transfer to air is not as efficient as a liquid collector, the infrastructure required has lower cost and complexity; basically a shallow metal box. Placement of PV panels can be vertical or angled. Using air as a heat transport medium compared to air has advantages such as no freezing and no boiling of collector fluid and no damage if leakage occurs [14].

A prototype double-pass photovoltaic-thermal solar air collector has been designed and fabricated and its performance over a range of operating conditions was investigated by Yusuf[39]. The absorber of the hybrid photovoltaic/thermal (PV/T) collector under investigation consists of an array of solar cells for generating electricity, compound parabolic concentrator (CPC) to increase the radiation intensity falling on the solar cells and fins attached to the back side of the absorber plate to improve heat transfer to the flowing air. The schematic diagram of the thermal collector is shown in figure 2.12. The result shown the electrical performance of the collector increased by 10% of the predicted value and without thermal collector was reduced 50%. Electricity production in a PVT hybrid module decreases with increasing temperature of the air flow.

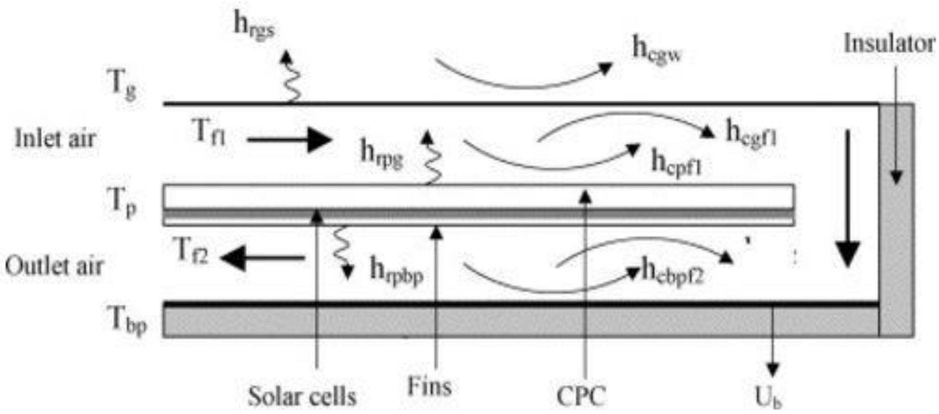

Figure 2.16: The schematic model of the double-pass PVT with CPC and fins.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the hardware, software, method and process that applied in this project to archive the objectives. All details on how the project has been conducted are discussed in this chapter. The project was composed of a PV module of Poly-crystalline type 50W rated power are combined with a solar thermal collector. The method to cool the panel is using water as working fluid to extract the excess heat of solar panel.

Microcontroller data acquisition for the PVT system will be made up by using Arduino Uno and three type of sensor. The experiment will be conducted at an interval of five hours in which the values of voltage, current, power and photovoltaic panel operating temperature and light intensity will be stored in the data logger. The performance of solar panel with the thermal collector and without thermal collector will be analyzed based on the data that saved in the data logger.

3.2 Project implementation flow

The first step conducts this project is by identifying the objectives and problem statement. All the method and process that carry out is to meet the objectives of this project. Study about concentrating of the photovoltaic and thermal collector. Concentrating is a process focus the sunlight to a small area of the solar panel. The thermal collector is a process produces heat energy from sunlight. Designing the concentrator by using silvered glass mirror. The thermal collector is designed using copper pipe and aluminum sheet. Data acquisition is created to measure voltage, current, temperature and light intensity.

The data logger is set up to collect all the data for analyzing the performance of PVT solar panel. When the hardware and software are complete, the whole system of PV thermal collector is set up testing the performance. Measure voltage, current, temperature and light intensity for PV thermal collector and PV without a thermal collector. All the data will be saved and analyzed. The last step is making a conclusion about the performance of PV with and without a thermal collector. figure 3.1 below shown the flow chart of this project.