Solar Panel Efficiency Characterization Using Sun Tracking Device and Cooling System

by

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Chapter 1

INTRODUCTION

Nowadays, the generation of electricity comes with a high price. The coals and fuels that are being utilized to generate electricity in the power plant are getting more expensive as we continue to use them. While The demand of energy is constantly increasing. Industry and consumers must think of other ways of generating energy with a low-cost price. Renewable Energy and energy conservation are one of the solutions to this problem in such a way that it sustains the natural resources and reduce the amount of carbon dioxide emissions of power plants. Renewable energy is generated by harvesting natural renewable resources. Renewable energy plays a vital role in producing an eco-friendly environment because it's clean and sustainable. In 2015, a share of 15% of renewable energy could grow to 63% of the primary energy supply in 2050, as renewable energy mixed with a high utilization efficiency can reduce 94% of emissions and can supply two-thirds of the global demand for energy. A popular type of renewable energy is the solar power since it can be used to generate electricity, either by using the sun's heat to drive a heat engine or by using the sun's energy with the use of a solar cell and provide a source of electricity. To combat the higher cost of electricity, households and establishments comes up with solutions to lessen their electric bill through net-metering, by installing solar panels on their roofs. Solar-powered photovoltaic (PV) use semiconducting materials that are photovoltaic, to convert sunlight directly into electricity. However, the behaviors of these renewable sources are dependent on weather and climate. This natural occurrence makes it less predictable compared to existing conventional energy sources. Studies and researches have been done to increase the efficiency of solar panels.

Many studies and research have been done in order to increase the efficiency of solar panels. A solar tracking hardware was implementated was proposed to tracks the Sun's movement throughout the day. The solar tracker is able to track the maximum sunlight available throughout the day by rotating accordingly (V. Sharma and V. K. Tayal, 2017). Solar concentrators are ways of increasing efficiency, one particular research made use of a concentrator with solar tracking system (M. Bálský & R. Bayer, 2016). Performance evaluation from another research shows that a solar panel can generate output power above 60% of its rated value for only six hours of a day. A comparison was made for a Sensor based controlling mechanism and or a Timer based controlling mechanism for solar panels, to see which one was more optimal for use. A thermal ventilation system was also proposed in order to decrease the operating temperature of a solar panel, results showed that the system with the ventilation system increased the voltage and current (B. Sreewirote, A. Noppakant and C. Pothisarn, 2017)

Based on our research, solar panel can be enhanced using a sun tracking device, cooling system, concentrator, and algorithm in order to increase its efficiency. For the individual techniques, it was able to increase the efficiency of solar panels but failed to reach its maximum efficiency. In some cases, efficiency of solar panel is based on the season or the climate of the country. Other countries especially those located at the top and bottom part of the earth receives the least amount of sun rays so they cannot get a high amount of energy from the solar panel. Unlike in the countries located at the central part of the earth or near the equator, they harvest the highest amount of energy they can get from the sun since they receive abundant amount of sun rays throughout the day.

The main objective of this study is to obtain the maximum efficiency of solar panel from its normal performance by using the combination of cooling system and sun tracking device technique. The secondary objectives of this study are:

1. To characterize the performance of the implemented cooling systems and sun tracking devices on the solar panel.
2. To compare the performance (power output, efficiency) of the implemented systems and to integrate them into a new system that alternates their performance based on which system has a better efficiency during a particular time of the day.
3. To present the parameters measured through a Graphical User Interface (GUI)

This study aims to have a longer peak hours in harvesting sun light of the solar panel. Improving the performance of the solar panel, makes the power output increases. When the power output of the solar panel increases households and other electric consumers will have an cheaper energy source through the help of the sun light. Cheaper production cost will cause to lower the price of the electricity. If the electricity will be cheaper prices of the product in the market will also be lower since many of consumers uses electricity in production of goods. This will also be an environmental friendly alternative energy source since thermal power plants produce eco waste that can harm to humans, animal and to the nature.

The scope of the study is focused on increasing the peak hours of the solar panel by utilizing the use of both sun tracking and cooling system techniques such as individual system's implementation and alternate implementation based on their performance according to the time of the day or temperature. The sun tracking devices tracks the abundant amount of the sunlight throughout the day. The cooling system decreases the operating temperature of a solar panel. The output data of both system must be collected in order to compute the efficiecy of each system. the efficiency obtained must be graphed to be able to determine which system is most efficient during a particular time of the day. The alternate implementation of both system will dependent on the comparison of the efficiency curve of the individual system's implementation. This study does not cover the type of solar panel to be used and selecting the best location of the solar panel.

Chapter 2

REVIEW OF LITERATURE

2.1 Solar Panel

Solar panels are one of the first thing that comes into our mind when it comes to renewable energy [1]. Solar panel is one of the cleanest sources of electricity since it does not produce anything that can harm environment. Solar panels are commonly installed on the roofs of limited number of residentials and commercial establishments [2]. Solar panel absorbs the sunlight and convert it to electricity. They called it “solar” panel since the highest amount of light came from the sun. Scientist called it photovoltaic which means the conversion of light to electricity [3]. It can be a good investment for anyone to install solar panels, since they will be able save money by generating their own electricity. But solar panels can only produce low amounts of energy, that's why there are many studies dedicated to enhance the efficiency of the solar panel. Some of the studies uses sun tracking device to follow the rays of the sun wherever the position of the sun while in another studies uses cooling systems to maintain the ideal temperature of the solar panel in producing greatest amount of electricity.

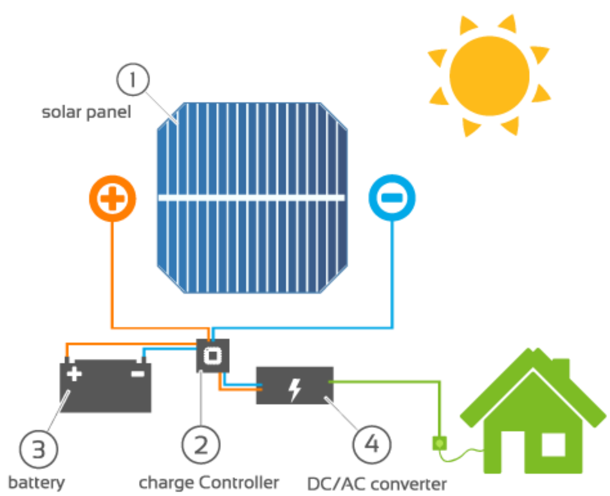


Figure 2.1 Schematic Diagram of Home Solar Panel

The cycle of supplying electricity of solar panel into households is when solar panel generated electricity it goes directly to the charger controller then it goes into the battery other charges will goes to the inverter after it pass into the inverter the Direct Current that produce by the solar panel will now be converted into Alternating Current which can now be usable as we can see on the figure 2.1. There are two types of solar panel that is most suitable for residentials which is the monocrystalline and the polycrystalline. This two is almost the same but monocrystalline is a little more efficient and expensive than polycrystalline [4].

2.2 Sun Tracking Device

Solar panels need to be in contact with sunlight in order to generate electricity. Solar panel are commonly installed in a fixed position which can only absorb the highest amount of sunlight from 9:00 am to 3:00 pm throughout the day. Proper harnessing of solar energy is very important since this kind of energy source is very dependent to the sunlight. Sun Tracking Device is one of the studies that aims to maximize the efficiency of the solar panel. If the solar panel is aligned to the rotation of the sun, the efficiency will get higher. Study shows that installing sun tracking device will make the efficiency higher by 31.17%. Sun Tracking Device makes the solar panel track the movement of the sun throughout the day. Studies shows that using a sun tracking device it can be able to harness 95% of solar energy throughout the day [5].

Different kinds of methods and components are used on tracking the sunlight. But in this study, the main components that were used are Solar panel, Light Dependent Resistor, 8051 Micro-controller, LC93D IC (motor driver IC), and a DC motor. For the micro-controller, the direction of the DC motor is dependent on the microcontroller with proximity switches employed. It also senses the light captured by the photo sensor, which is sensed by the IC 8051. Unlike most typical micro-controllers that has 40 pins, this micro-controller only has 20 pins and is required because of the 2 outputs for the DC motor. The motor driver IC is designed for controlling two motors at a time. And a permanent DC motor whose speed is minimized because of the gear box installed. Alternatively, the DC motor may be replaced with a stepper motor, but it has a higher current consumption. Below is a sample figure of the sun tracking hardware system and a sample assembly for the sun tracking solar panel. In the sun tracking solar panel, The LDR and photodiodes are placed on the top of the platform to detect the maximum sunlight it can capture. During maximum sunlight, the resistance of the photodiode is at minimum and a 0 signal is provided at the micro-controller so that the motor would stop at the maximum light intensity. When the photodiodes are shaded, the platform recalibrates and searches for the light position [5].

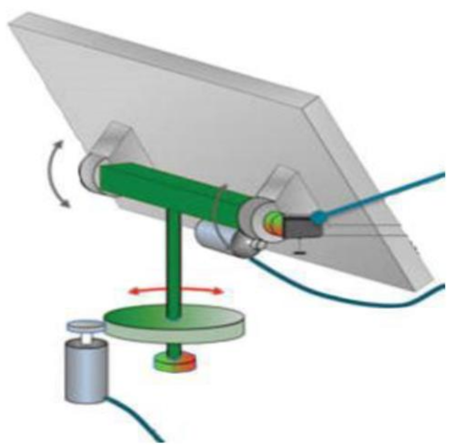


Figure 2.2 Sample Assembly for the Sun Tracking Solar Panel

The solar panel with a sun tracking device is deemed to be more efficient compared to a flat panel since it collects the maximum possible energy generated by the Sun, which can be seen on the figure below [5].

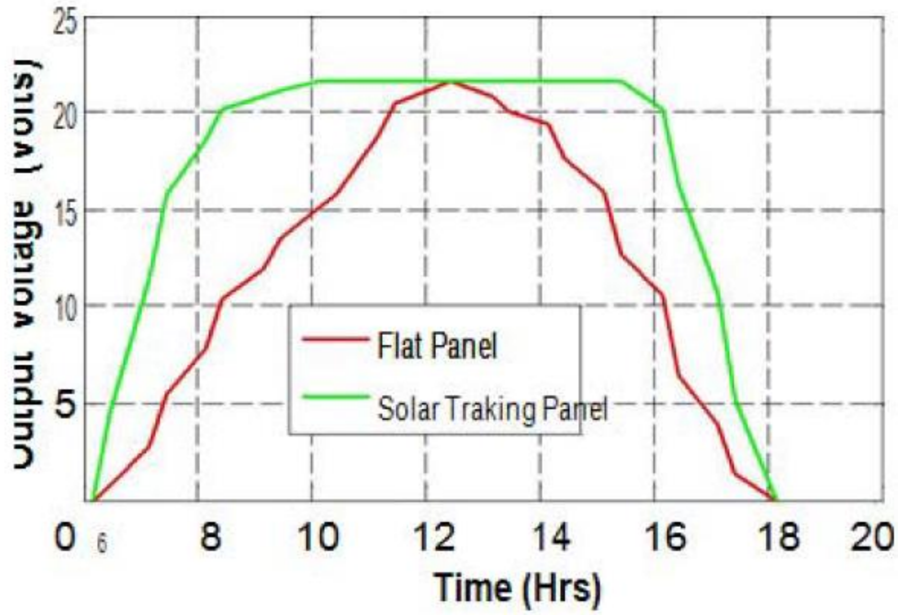


Figure 2.3 Comparison of generated output voltage between a solar panel with solar tracking device and without solar tracking device.

2.3 Light Dependent Resistor (LDR)

Light dependent resistor is made of high resistance semiconductor material [6]. It also known as photo resistor. the value of its resistance is 1M ohm in dark and decreases when interfaced with the presence of light. The value of the resistance is variable depending on the intensity of the light. This kind of resistor are commonly used a sensor in determining the presence or absence of light [7].

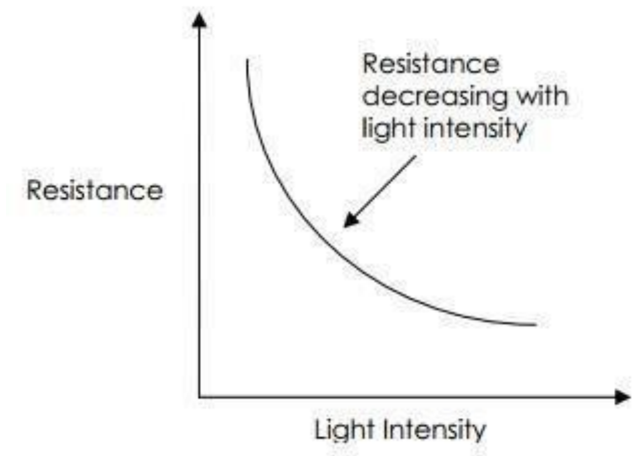


Figure 2.4 Resistance Vs. Light Intensity Curve

Photoresistors has two types, first is the intrinsic which uses semiconductor material such as silicon and germanium. photons fall under light dependent resistor that makes the electrons energize and move from valence bond to the conducting band. Thus, these electrons are able to conduct electricity. The higher amount of light that falls into the device, the higher number of electrons are discharge and the conductivity level will be greater, then this will result to decrease the value of the resistance. The other type is the extrinsic this is also made from semiconductor material dope with impurities. Over the existing valence band, these impurities or dopants makes a new energy band. Thus, due to small amount of energy gap, electrons need less energy to move to the conductive load. Either of these photoresistors, they just have same function and principles, as the incident light increases the level of conductivity increases or the resistance decreases [7]. Figure 2.2 show the graph of resistance vs. light intensity. these graphs show clearly the relationship of resistance and light intensity.

2.4 Servo motor

Figure 2.5 Servo Motor

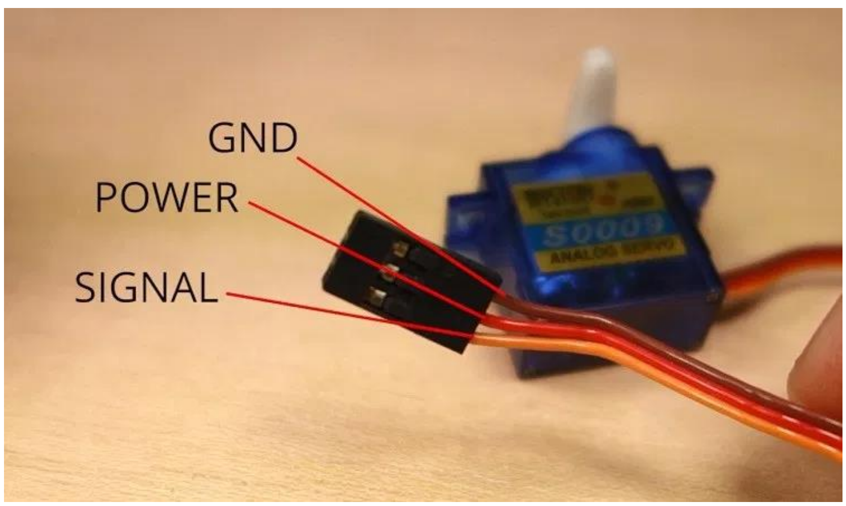


Figure 2.6 Servo Motor Wiring

Servo motor is a DC motor that rotates or push parts of the machine with great prescription. Servo motors are usually used in robots and in Radio-Controlled model car. In a robot, it serves as the joints to move their arms, legs or even the neck, while in Radio-Controlled model car servos used to control steering [8]. The servo motor is just simply made of from a DC motor, a gear mechanism, a control circuit and a position sensor. The DC motors energized by a battery and keep running at a low torque and high speed. The gear and the shaft links to the dc motor and decreases the speed to enough speed with a higher torque. the position sensor determines the position of the shaft and send the signal to the control circuit. The control circuit generates the signal from the position sensor and measures the distance between the actual position of the motor to the ideal position and properly controls the movement of rotation of the DC motor to the needed position. the servo motor usually has a voltage rating of 4.8V to 6V [9].

There are three types of servo motor that comes with the positional rotation, continuous rotation, and linear. the positional rotation is the usual type of servo motor. the output shaft has a limit of 180 degrees rotation. Continuous rotation servo is bit similar to positional rotation servo motor except that it doesn’t have a limit of rotation. the control signal is decoded as the direction and speed of rotation instead of the static position of the servo. the possible commands limits from causing the servo to rotate from the direction of clockwise and counterclockwise at different speeds, depending on the signal of the command. Linear servo is likewise similar to the positional rotation servo motor, however with extra gears that is typically rack and pinion mechanism to produce different output from circular to forward and backward [8].

2.5 Arduino

Arduino is an open source platform used to construct and program electronics. It can obtain and send data to most devices as well as to order the specific electrical device via the internet [10]. Typically, an Arduino is a microcontroller-based platform which develops an environment that implements the processing language that is based on a piece of software. It was originally designed for designers and programmers to create various electronic prototypes [11].

Arduino is used to create interactive objects by converting the inputs as a command for the output. Projects created through Arduino can be independent or they can interact with software that runs on a computer [11]. Today, Arduino is heavily used especially in microcontrollers because of its user-friendly setting. With an Arduino board, everything is possible, a small imagination could turn into a new project. As stated before, the Arduino composes a hardware and a software. The hardware of an Arduino board combines different components for it to work, namely [10]:

a) USB Plug: This is used to upload a program to the microcontroller, it also powers the Arduino board [10].
b) External Power Supply: This is also used to provide power to the board especially if the USB plug can't provide enough power for the prototype to work [10].
c) Reset Button: It resets the Arduino, it is typically used when there is a new command for the Arduino to execute [10].
d) Microcontroller: It receives and commands the information to the circuit [10].
e) Analog Pins (0-5): It is the input analog pins [10].
f) Digital I/O Pins: It is the digital input and output pins [10].
g) In-Circuit Programmer: It is another way to program the prototype [10].
h) Digital and Analog Ground Pins [10].
i) Power Pins [10].

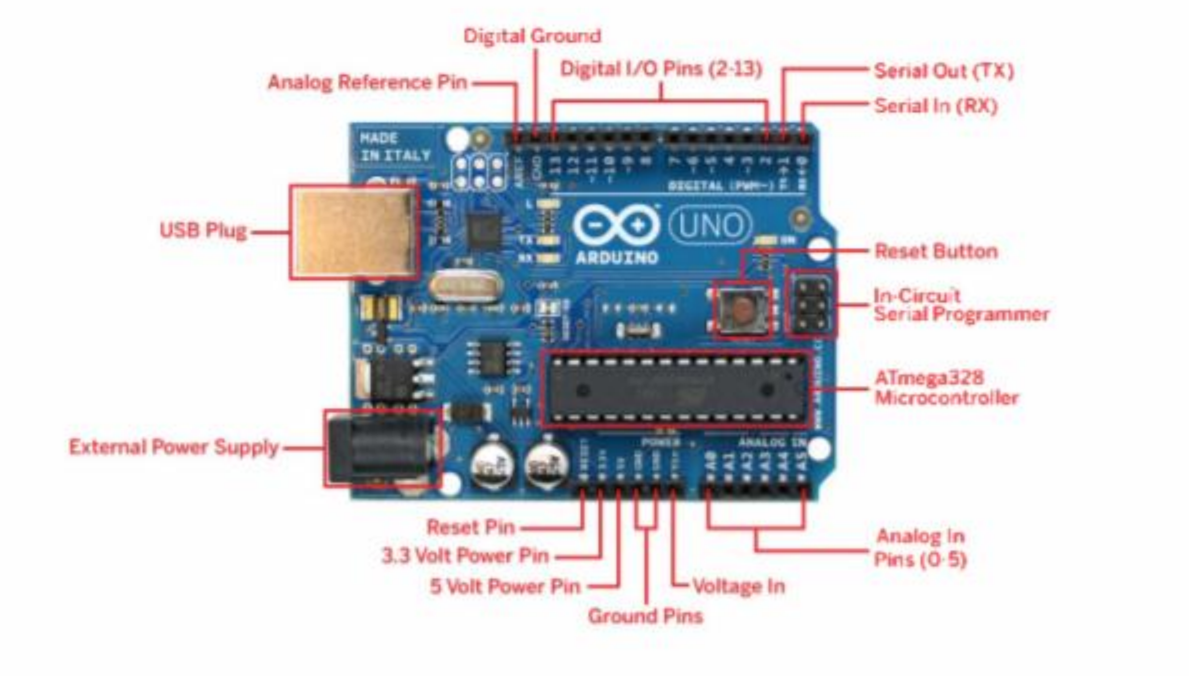


Figure 2.7 Arduino Board

The software of the Arduino is where the instructions that commands the hardware is placed. The Arduino IDE (Integrated Development Environment) namely has three parts [10]:

1. Command Area: This is where the menu such as File, Edit, Sketch, Tools, Help, and Icons such as Verify Icon, Upload Icon, New, Open, Save, and Serial Monitor can be found [10].
2. Text Area: This is where the code (typically a simplified C++ language) is placed to program the Arduino [10].
3. Message Window Area: This is where (the black area) the message of the IDE in verifying the codes can be seen [10].

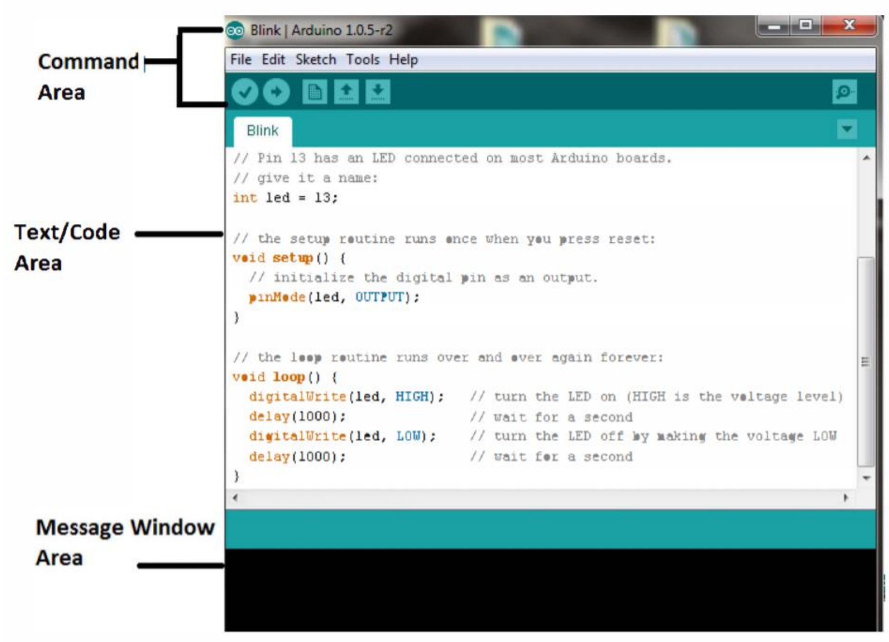


Figure 2.8 Integrated Development Environment

2.6 Relationship of the Power Generated of Solar Panels due to Sun's Position

Solar panels are much productive when their surface is in perpendicular to the sun's incoming rays. Two angles are used to plot the position of the sun in the sky, azimuth and zenith, and the angle of orientation of the solar panel is based on these two values. Azimuth refers to the angle based on the sun's position as it moves from East to West, with respect to South, throughout the day. Basically, it is the horizontal position of the sun [12].

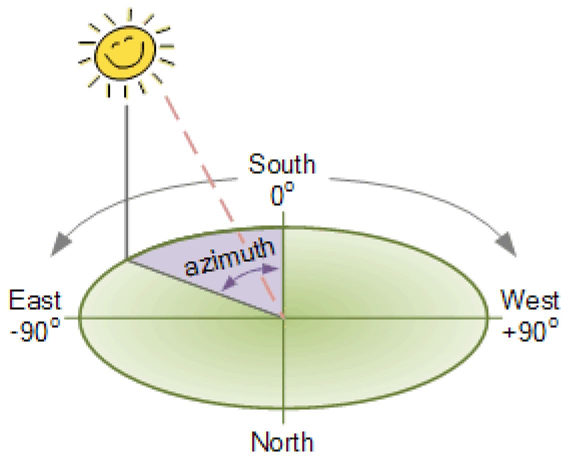


Figure 2.9 Solar Azimuth Angle

On the other hand, Zenith refers to the angle between the vertical and the sun's position. The sun's zenith angle varies depending on the time of the day. Generally, the Zenith angle is at 0 degrees on sunrise and sunset, while it is at 90 degrees during midday [12].

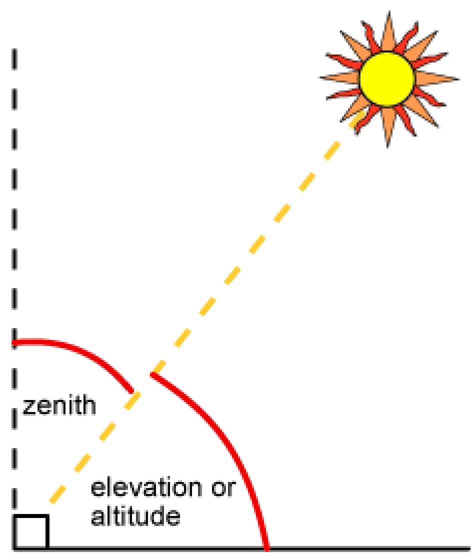


Figure 2.10 Solar Zenith Angle

To generate the maximum solar power output, solar panels require the exposure from direct sunlight. Thus, weather is also a factor to the solar panel's generated power. At a cloudy weather solar panels only absorbs 25% to 40% less solar energy when compared to a sunny day.

That is why it is best to place a solar panel on an area where there wouldn't be any material to block the solar panels to the sunlight [13].

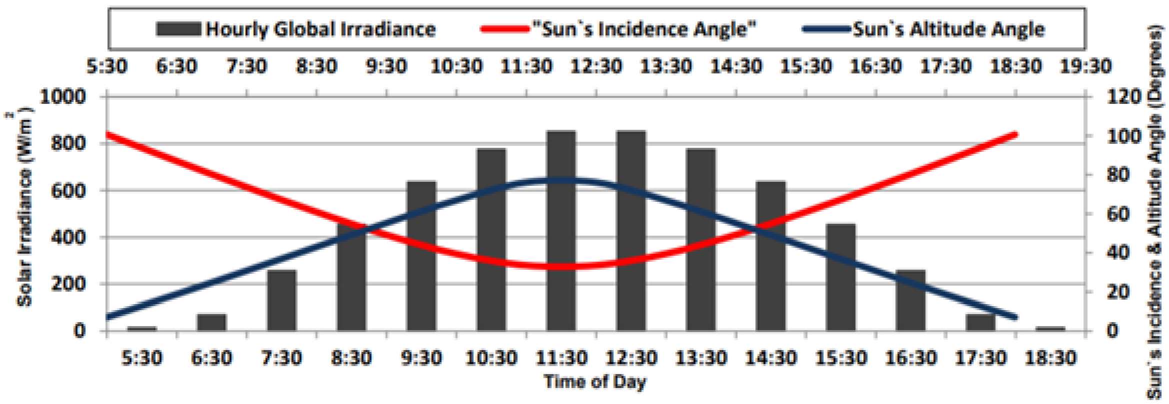


Figure 2.11 The Effect of the Sun's Position to the Solar Irradiance on a Tilted Panel Due to the Time of Day [14]

With a clear summer sky and no cloud coverage, a solar panel is mounted at 17 meters above sea level from the observation point. The graph from Figure 2.11 shows the effects of the sun's position to the solar irradiance on a tilted panel. Here the direct relation of the position of the sun and the global irradiance passing to the solar panel. It is very clear that the maximum hourly irradiance falls once the sun reaches the maximum altitude and the minimum value of the incidence angle. At Figure 2.12 we can see that the solar irradiance is directly proportional to the power output generated by the solar panel since the solar panel receives sunlight the most during midday where it is completely exposed to the sun [14].

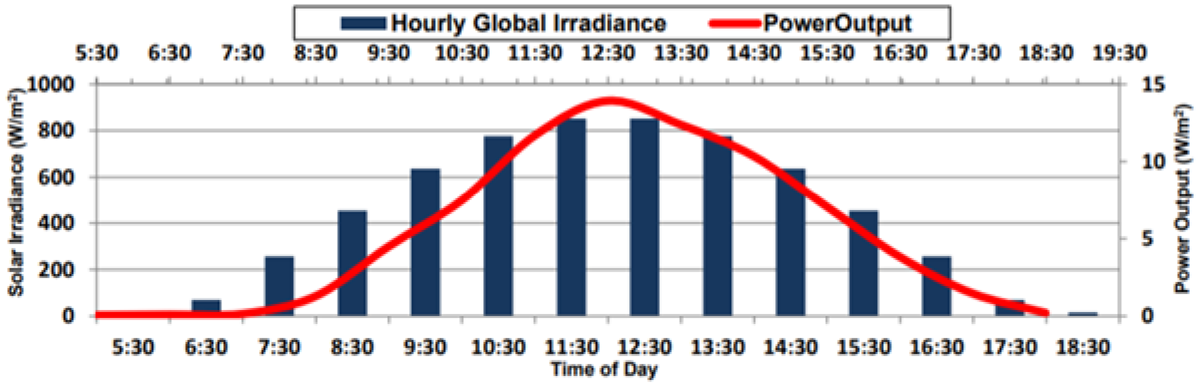


Figure 2.12 The relationship between Solar Irradiance and Power Output Due to the Time of Day

2.7 Temperature Efficiency

Solar PV cells absorb approximately 80% of the solar radiation incident. Depending on the cooling methods used for the PV cells, only a small proportion of the absorbed solar radiation is transformed into electrical energy and the remainder of the absorbed solar radiation is receded in the form of heat. The photovoltaic cell will use the whole visible spectrum as well as some IR spectrum as well. Based on the energy of the IR spectrum, the radiation with a longer wavelength is not enough to excite the electrons to trigger current flow. However, high-energy radiation can generate current flow. The semiconductor material's bandgap energy is also correlated with the PV cell's minimal efficiency. The electrical power output drop is around (2/10) % – (5/10) % for every 274.15 K increase in photovoltaic cell temperature due to the cell's temperature dependence property. This is called the Temperature Coefficient of Photovoltaic cell. Overheating significantly reduces panel efficiency. The biggest challenge in photovoltaic panel operation is nonetheless overheating due to extreme solar radiation and high ambient temperature. The PV curve is the interrelationship between the power output (P) and the output voltage (V) in which the temperature of the solar irradiance and the PV cell is maintained constantly [15].

The figure shows that when the temperature increases, the power output of the solar cell decreases. As a result, the panel output is significantly affected by PV cell heating [15].

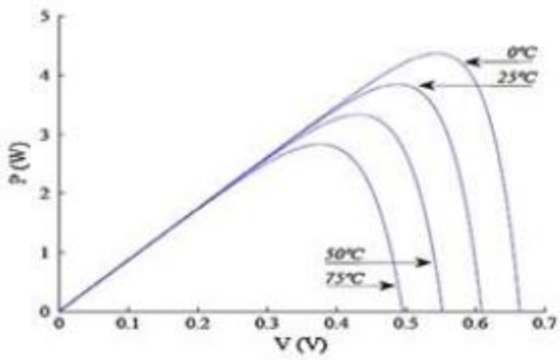


Figure 2.13 Power and Voltage Relationship Due to Temperature

2.8 Cooling Methods/Techniques

A photovoltaic (PV) system efficiency varies depending on several parameters such as temperature. The absorbed solar radiation that hasn't been converted into electrical energy proceeds to become a thermal energy and leads to a reduction in electrical efficiency. The temperature of a photovoltaic system is one of the key components in ensuring the improvement of its electrical efficiency. The largest reduction in temperature of the PV module was obtained by simultaneously spraying water on the front and backside of the PV panel. The water spray cooling method is the cooling technique that produces the lowest temperature to provide a better electrical efficiency compared to other cooling techniques. It is proven that the water spray cooling method is very effective when it comes to improving electrical efficiency and power output. In the effect of the water spray flow variation, it was discovered that the increase in electrical efficiency has a linear relationship with the applied water spray flow magnitude. The effects of the cooling system can be seen on the figures below and it shows the significance in change of temperature in terms of the top, bottom, and ambience has a difference of 14 to 22 degrees Celsius [16].

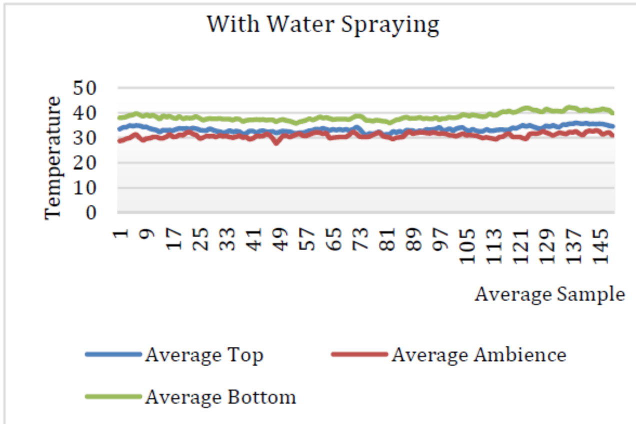


Figure 2.14 Comparison of temperature (Top, Bottom, Ambience) with water spraying as the cooling method on the PV panel [16].

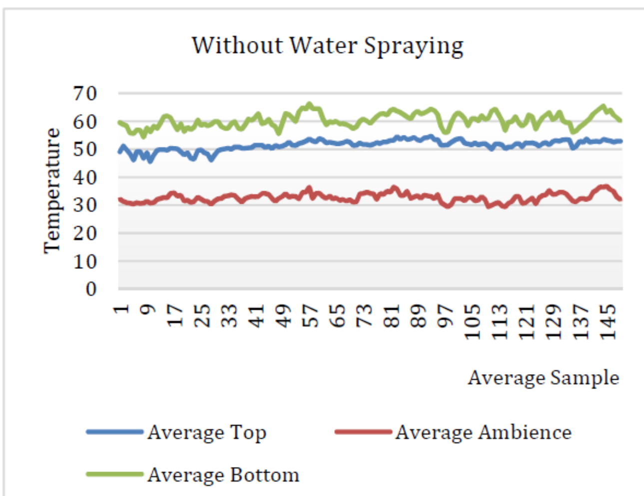


Figure 2.15 Comparison of temperature (Top, Bottom, Ambience) without water spraying as the cooling method on the PV panel [16].

The temperature of the PV system leads to its effects on the efficiency of the PV module system, which can be seen on the figures below.

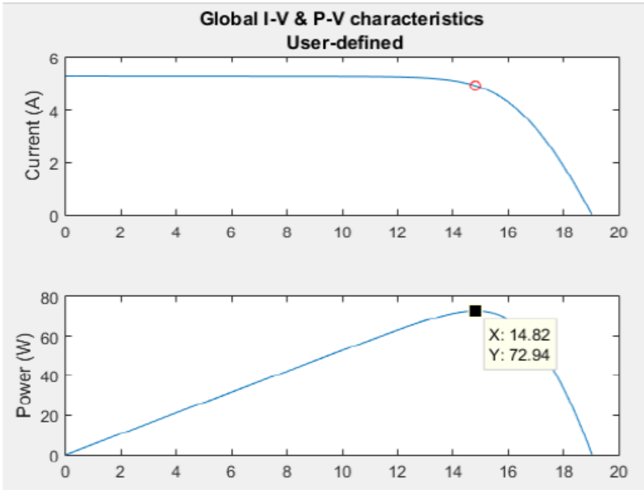


Figure 2.16 Current-Voltage curve and Power-Voltage Curve of the PV system without water spraying [16].

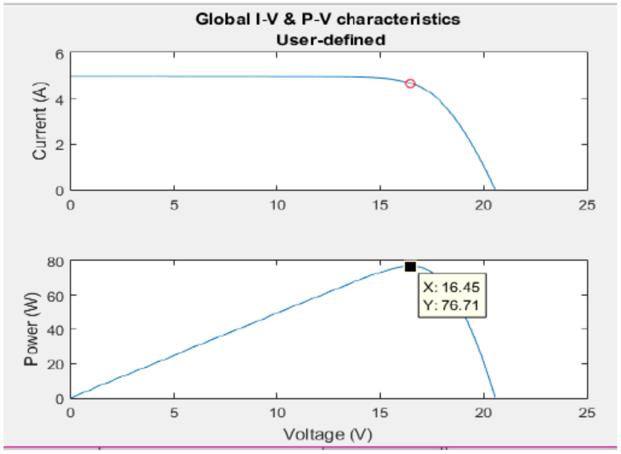


Figure 2.17 Current-Voltage curve and Power-Voltage Curve of the PV system with water spraying [16].

It can be observed that the decreasing temperature resulted into a better efficiency. Thus, the water spraying method as a cooling technique is a useful technique to be implemented to reduce the temperature of solar PV panels. Asides from cooling another advantage of this cooling technique is that it delivers self-cleaning since the water flows from the top of the panel to reduce any kinds of debris spots to increase its life span [16].

2.9 Solar Panel Efficiency

In calculating the solar panel's electrical conversion efficiency, the output power was measured through the readings of an ammeter and voltmeter. Other parameters that were measured are the surface temperature of the solar panel and the real time solar radiation intensity in terms of watt per squared meter. Additionally, the inlet and outlet temperature of water flow and the flow rate of the water were also measured [17].

And here the solar panel's efficiency is calculated using this formula:

$$\eta = \frac{P_{max}}{AI}$$

Where η is the solar panels' electrical conversion efficiency, P_{max} is the maximum power generated by the solar panel in watts, A is the solar panel's surface area is squared meter, I is the solar irradiance absorbed by the solar panel in watts per squared meter [17].

The theoretical cell electrical efficiency (ηe) and this whole parameter rely on the cell temperature [17].

$$\eta e = \eta o[1 - \beta(Tc - To)] \qquad (1)$$

$$\eta e = \int VI\ dtAc \int G(t)dt \qquad (2)$$

Here, the solar panel's electrical efficiency is described by the following equation [17]:

$$\eta o = Vmp\ ImpG \qquad (3)$$

The thermal efficiency is calculated by this formula [17]:

$$\eta th = m \cdot Cp \int (Tout - Tin)\ dtAc \int G(t)dt \qquad (4)$$

Lastly, the efficiency of a hybrid PV/T system is determined through this formula:

$$\eta total=\eta th+\eta e=m\cdot Cp\int(Tout-Tin)dt+\int VI\ dtAc\int G(t)dt \quad (5)$$

Equations 2 and 4 shows that solar irradiation and other parameters affected by the solar irradiation, such as the solar panel's inlet and outlet temperature, the voltage and current of the PV system, are a function of time. Thus, the equation is integrated with respect to time [17].

In figure 2.18, it shows the peak efficiency of the solar panel against the cooling water's mass flow rate. It can be seen that the performance of the solar panel is better when it has two liters per mass flow rate of cooling water. It also shows that exceeding two liters of water flow per hour does not stay in the sponge, because of the water absorption capacity of the sponge, which results into a decrease of efficiency on the solar panel. Thus, 2 liters per hour is the ideal flow rate of water [17].

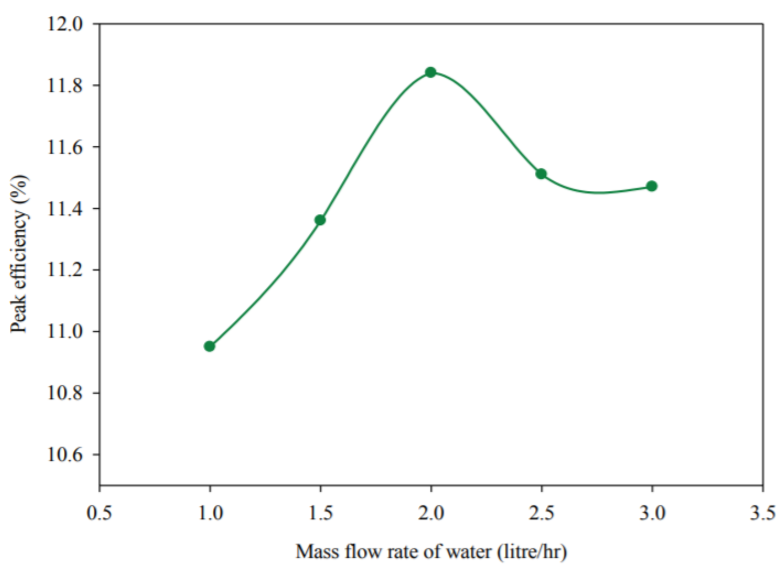


Figure 2.18 Peak Efficiency of the Solar Panel Against the Cooling Water's Mass Flow Rate [17].

In figure 2.19, it shows the comparison of the solar panel's temperature between cooling and without cooling. It can be seen that the solar panel with two liters per hour of flow rate of water as a cooling decreases the temperature with a peak of 4^0 C and an average of 1.7^0 C compared with an ordinary solar panel [17].

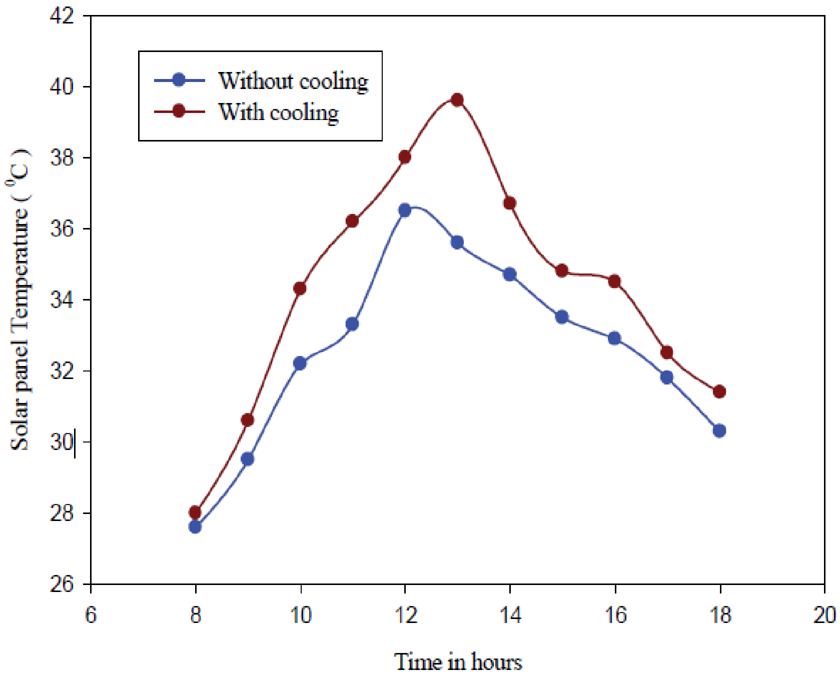


Figure 2.19 Comparison of the Solar Panel's Temperature Between Cooling and Without Cooling [17].

In figure 2.20, it shows the comparison of the output power of the solar panel between cooling and without cooling. Here it shows the characteristics of the output power as time progresses. It can be observed that the output power of both solar panel peaks between 12:00 and 13:00 and the solar panel with a cooling system has a higher output power at a peak of 6.4% and an average of 4.3 when compared to an ordinary solar panel [17].

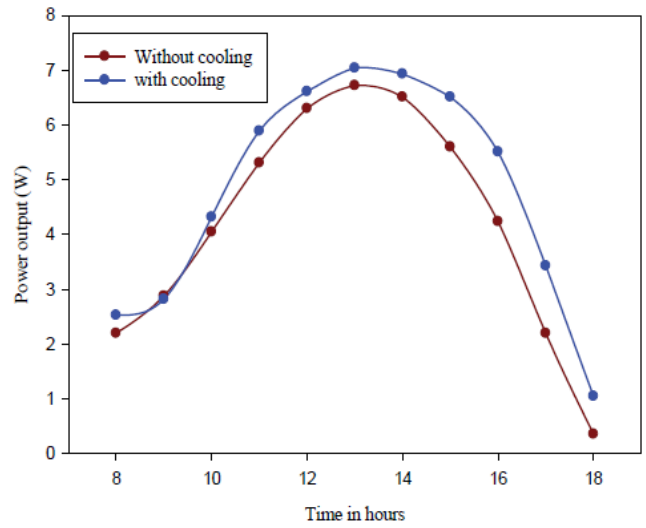


Figure 2.20 Comparison of the Output Power of the Solar Panel Between Cooling and Without Cooling [17] .

In figure 2.21, it compares the solar panel's output efficiency per hour between cooling and without cooling. Based from the results, the efficiency of the solar panel with a cooling system increases by a maximum value of 2.69% and an average of 0.39% when compared to an ordinary solar panel [17].

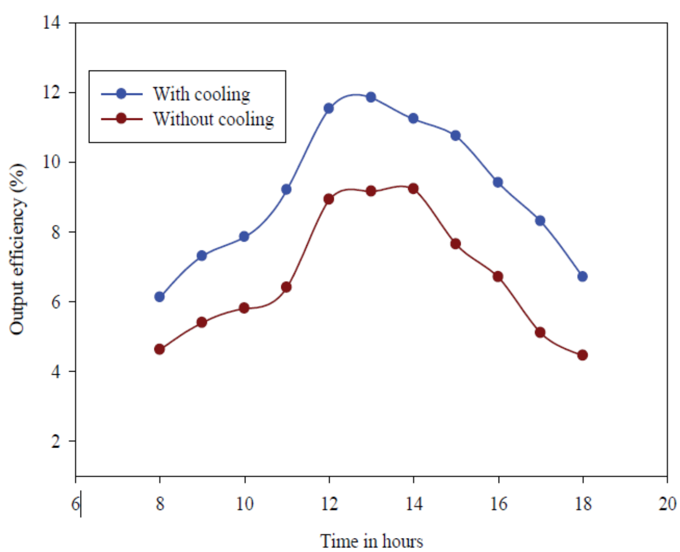


Figure 2.21 Comparison of the Output Efficiency of the Solar Panel Between Cooling and Without Cooling

Chapter 3

“Solar Panel Efficiency Characterization Using Sun Tracking Device and Cooling System “

INTRODUCTION

Nowadays, generation of electricity comes with a high price. The coals and fuels that are being utilized to generate electricity in the power plant are getting more expensive as these resources continues to deplete. While The demand on energy is constantly increasing. Industry and consumers must think of another way in generating energy with a low-cost price. Renewable Energy and energy conservation are one of the solutions to this problem in such a way that it sustains the natural resources and reduce the amount of carbon dioxide emissions of power plants. Renewable energy is generated by harvesting natural renewable resources. Renewable energy plays a vital role in producing an eco-friendly environment because it’s clean and sustainable. In 2015, a share of 15% of renewable energy could grow to 63% of the primary energy supply in 2050, as renewable energy mixed with a high utilization efficiency can reduce 94% of emissions and can supply two-thirds of the global demand for energy. A popular type of renewable energy is the solar power since it can be used to generate electricity, either by using the sun’s heat to drive a heat engine or by using the sun’s energy with the use of a solar cell and provide a source of electricity. To combat the higher cost of electricity, households and establishments comes up with solutions to lessen their electric bill through net-metering, by installing solar panels on their roofs. Solar-powered photovoltaic (PV) use semiconducting materials that are photovoltaic, to convert sunlight directly into electricity by exciting electrons in silicon cells using the photons of light from the sun. However, the behaviors of these renewable sources are dependent on weather and climate. This natural occurrence makes it less predictable compared to existing conventional energy sources. Studies and researches have been done to increase the efficiency of solar panels.

Many studies and research have been done in order to increase the efficiency of solar panels. A solar tracking hardware implementation was proposed which tracks the Sun’s movement throughout the day. The solar tracker is able to track the maximum Sunlight available throughout the day by rotating accordingly. It is able to harness 95% of the solar energy available throughout the day (V. Sharma and V. K. Tayal, 2017). Solar tracking features and solar concentrators are ways of increasing efficiency, one particular research made use of a concentrator with solar tracking system, and it shows the performance of combined generation of electrical power and heat from solar radiation. (M. Bálský & R. Bayer, 2016). Performance evaluation from another research shows that a solar panel can generate output power above 60% of its rated value for only six hours of a day from 9.00 am to 3.00 pm in Pondicherry, India. A comparison was made for a Sensor based controlling mechanism and or a Timer based controlling mechanism for solar panels, to see which one was more optimal for use. A small sized solar cells are used to detect the position of the sun and to give signal to the microcontroller (A. J. Ahmed and S. N. Khan,2014). A thermal ventilation system was also proposed in order to decrease the operating temperature of a solar panel, results showed that the system integrated with the thermal ventilation system enabled the output of voltage, current, and power to increase.(B. Sreewirote, A. Noppakant and C. Pothisarn, 2017)

Based on our research, solar panel can be enhanced using a sun tracking device, cooling system, concentrator, and algorithm in order to increase its efficiency. For the individual techniques, it was able to increase the efficiency of solar panels but failed to reach its maximum efficiency. In some cases, efficiency of solar panel is based on the season or the climate of the country. Other countries especially those located at the top and bottom part of the earth receives the least amount of sun rays so they cannot get a high amount of energy from the solar panel. Unlike in the countries located at the central part of the earth or near the equator, they harvest the highest amount of energy they can get from the sun since they receive abundant amount of sun rays throughout the day.

The main objective of this study is to obtain the maximum efficiency of solar panel from its normal performance by using the combination of cooling system and sun tracking device technique. The secondary objective of this study are:

1. To characterize the performance of the implemented cooling systems and sun tracking devices on the solar panel.
2. To compare the performance (power output, efficiency) of the the implemented systems and to integrate them into a new system that alternates their performance based on which system has a higher/better efficiency/power output during a particular time of the day.
3. To present the parameters measured through a Graphical User Interface (GUI)

This study aims to have a longer peak hours in harvesting sun light of the solar panel. Improving the performance of the solar panel, makes the power output increases. When the power output of the solar panel increases households and other electric consumers will have an cheaper energy source through the help of the sun light. Cheaper production cost will cause to lower the price of the electricity. If the electricity will be cheaper prices of the product in the market will also be lower since many of consumers uses electricity in production of goods. This will also be an environmental friendly alternative energy source since thermal power plants produce eco waste that can harm to humans, animal and to the nature.

The scope of the study is focused on increasing the peak hours of the solar panel by utilizing the use of both sun tracking and cooling system techniques such as individual system's implementation and alternate implementation based on their performance according to the time of the day or temperature. The sun tracking devices tracks the abundant amount of the sunlight throughout the day. The cooling system decreases the operating temperature of a solar panel. The output data of both system must be collected in order to compute the efficiecy of each system. the efficiency obtained must be graphed to be able to determine which system is most efficient during a particular time of the day. The alternate implementation of both system will dependent on the comparison of the efficiency curve of the individual system's implementation. This study does not cover the type of solar panel to be used and selecting the best location of the solar panel.

Methodology

3.1 Conceptual Framework

The diagram describes how is the flow of the study.

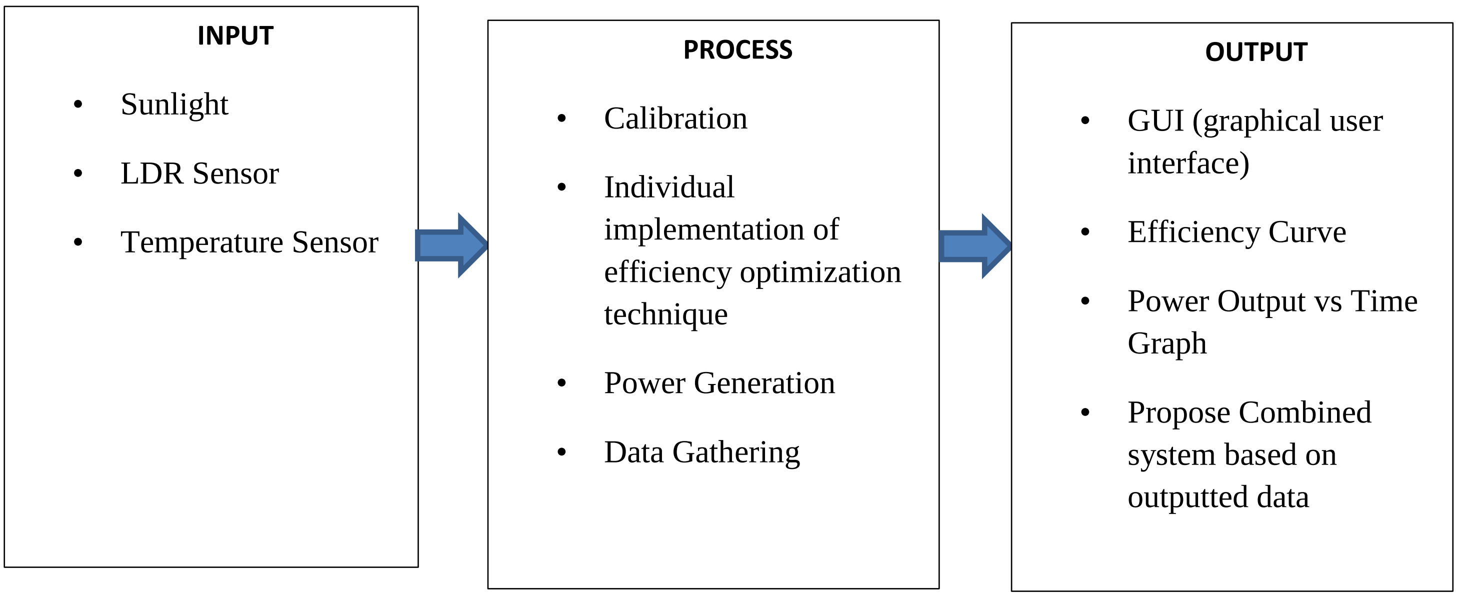


Figure 3.1 Conceptual Framework

Sunlight is captured by the solar panel. The solar panel will convert the solar energy into electricity or in scientific term photovoltaics. To have a more efficient energy harvesting from the sun, the solar tracking system will do its job to follow the sun's rays as the day goes by. The LDR will serve as the sensor to detect the light coming from the sun. The signal from the LDR is sent to the arduino to be processed. The output of the arduino from the LDR goes to the servo motor which calibrates the position of the solar panel to the position of the sun light. While the solar panel harvest energy from the sun, the efficiency decreases as its temperature increases. To lessen the heat of the solar panel, the cooling system is implemented to lower the temperature of the panel. The sensitivity of the LDR should be adjusted to most reliable movement of the servo motor. The calibration of LDR is done through the use of arduino. As electricity is produced, the power, current, voltage and time is measured accordingly. All the data gathered is plotted by the graphical user interface to compare the results.

3.2 System Flow Chart

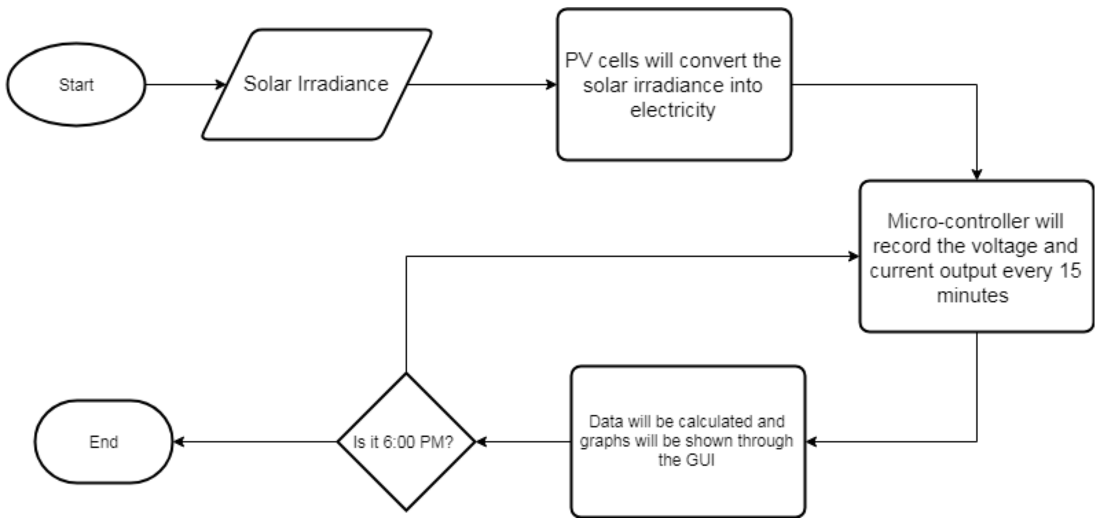


Figure 3.2 System Flow Chart

The System flow chart shows the step by step function on how the researchers will collect the output of the solar panels with different configurations. The first step of the system flow chart is to generate power through the PV panel. Since the PV panel will be active, the micro-controller will record the data every 15 mins. The Data that was gathered will then be computed to measure the efficiency of the panel and then output the calculated data through a graph using a GUI.

3.3 Design of Sun Tracking System

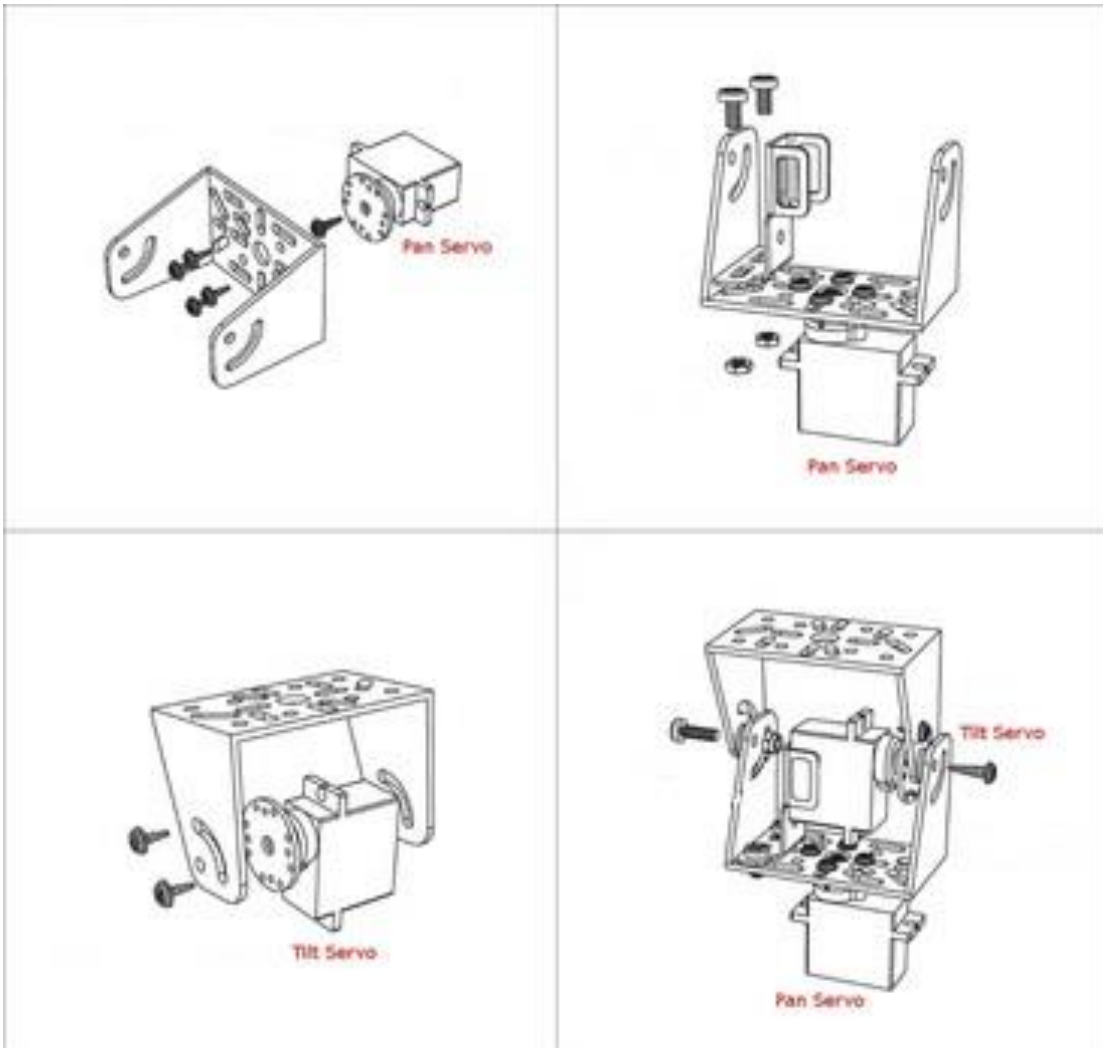


Figure 3.3 Typical Dual-axis system design

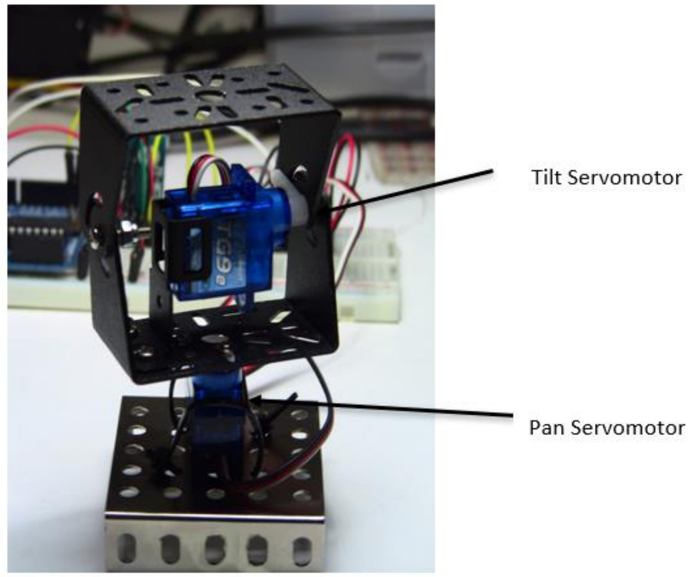


Figure 3.4 Dual-axis Servo & brackets (note: photo is taken from Google)

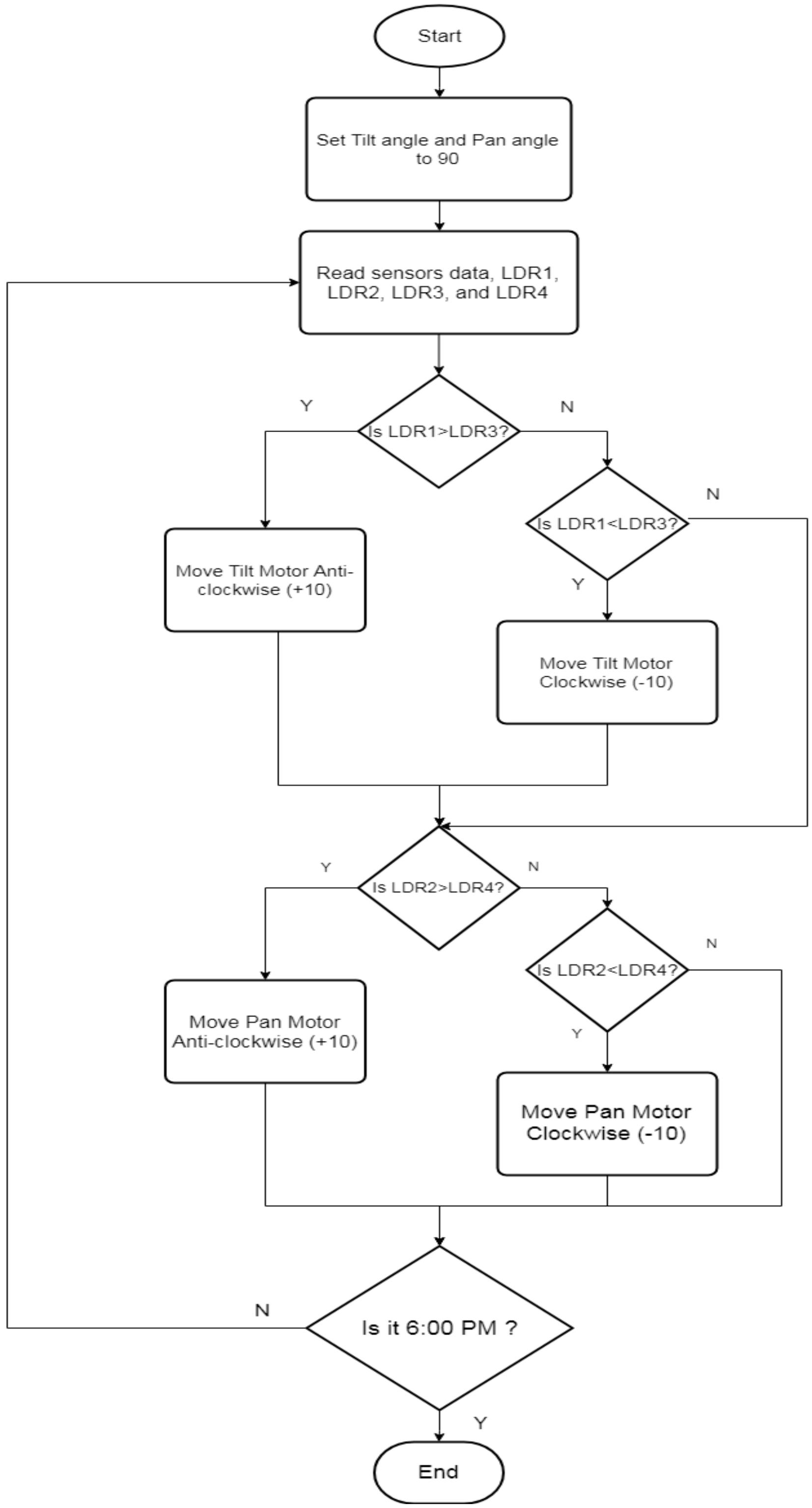


Figure 3.5 Sun Tracking Flow Chart

In design of the Sun tracking device, an IEC 62817 standard for solar's sun tracking by International Electrotechnical Commission and UL3703 standard for solar tracker was consider by the researchers in designing of the device. The LDR is mounted on the top of the platform to sense the maximum sun light. When the sensor senses the maximum light, its resistance becomes very low and a 0 signal is provided to the microcontroller to stop the motor in maximum intensity position. The motor remains standstill until the LDR senses the maximum light. The design compose of two servo motor for dual axis sun tracking system to catch the abundant amount of sunlight. The primary metal bracket is attached into the servo motor in order to rotate in horizontal axis up to 360 degrees. The secondary servo motor is place inside the primary bracket and the secondary is attached to the primary bracket to rotate horizontally up to 180 degrees.

3.4 Design of PV Cooling System

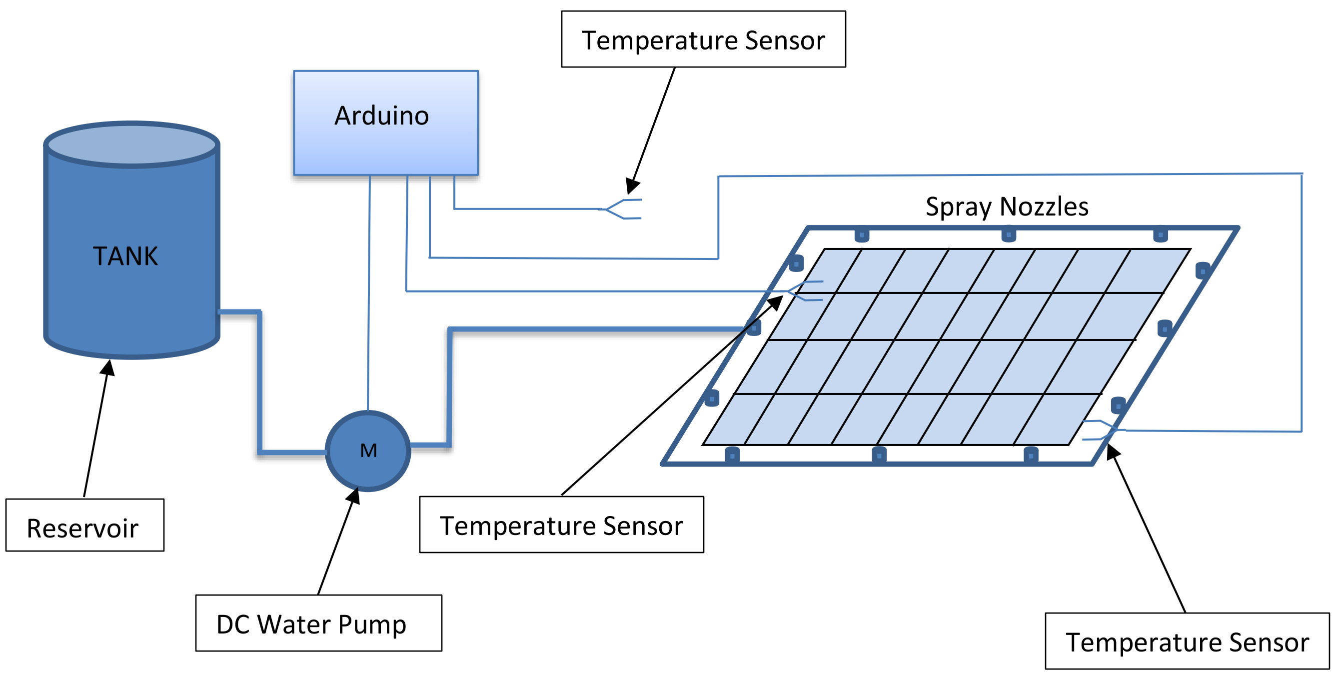


Figure 3.6 Hardware Output

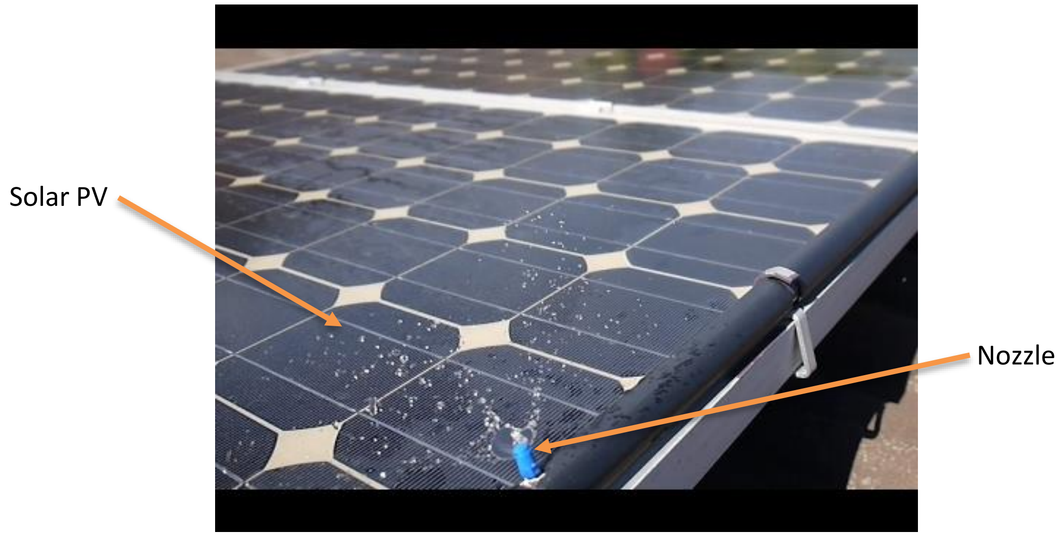


Figure 3.7 Water Spray Cooling System Design (note: photo is taken from Google)

The design of the water cooling system of the PV consist of water pump and pipe, spray nozzles, temperature sensor, arduino and tank. The water is stored in tank that is connected to the cooling system through the water pipe. The water pump is used to be able to flow the high pressure water across the pipeline and nozzle placed above the solar panel. The water is sprayed into the front glass surface of the solar panel. Thermocouple type-k was used as an temperature sensor and it is placed at the ambient, front and back of the solar panel. The water sprays on the solar panel if the temperature sensor sense that the operating temperature of the solar panel is above to its efficient operating temperature. The actual set-up of PV Water Cooling System is shown in Figure 3.5 while the schematic representation of the cooling system shown in figure 3.4. the entire system is connected to the Arduino to be able to obtain the input and output reading measurements.

3.5 Solar Panel Efficiency Formula

The efficiency of the solar panel is computed using the formula:

$$\eta = \frac{P_{max}}{AI}$$

Where

η, is the efficiency of the PV panel (%)

P_{max}, is the maximum power output of PV panel (W)

A, is the surface area of the panel (m^2)

I, is the solar irradiance towards the panel (W/m^2)

The maximum power output is based on the readings of the voltmeter and ammeter.

3.6 Solar Tracking Calibration

Before conducting the actual testing of the system, calibration of the LDRs and Servo-motors must first be observed. The table below would be used in Solar Tracking Sytem, four LDRs are placed in the four quadrants of the PV panel, If the PV panel is not perpendicular to the sunlight, the servo-motors will move accordingly. The IEC 17025 standard for calibration by the International Electrotechnical Commission was followed.

Sun's position	Tilt Servo-motor Angle	Pan Servo-motor Angle
Central		
Down-Right		
Down-Left		
Up-Right		
Up-Left		
Up		
Down		
Right		
Left		

Sun’s position	LDR 1 Sensitivity	LDR 2 Sensitivity	LDR 3 Sensitivity	LDR 4 Sensitivity
Central				
Down-Right				
Down-Left				
Up-Right				
Up-Left				
Up				
Down				
Right				
Left				

3.7 Cooling System Calibration

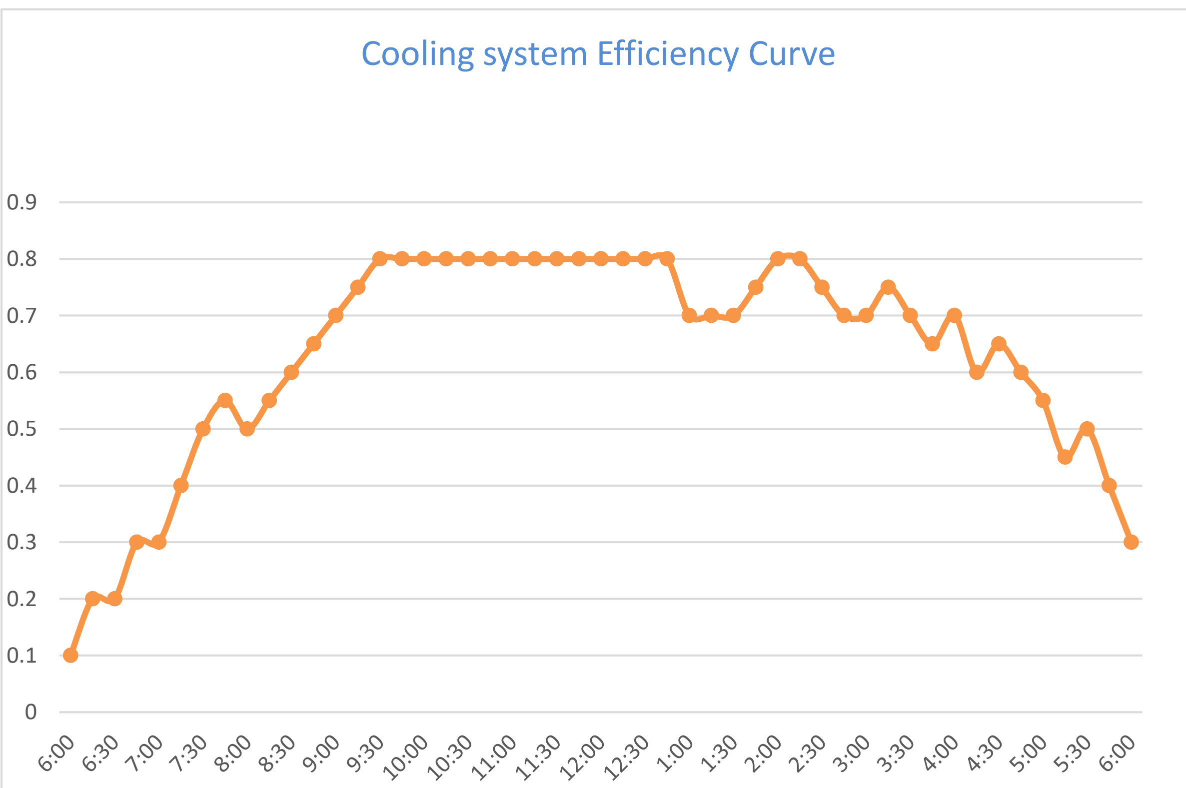
Before proceding for the actual testing of the system, calibration of the temperature sensor must be done. The table below would be use for the cooling system, three thermocouple will be placed at the front & back surface and ambient of the solar panel. If the solar panel exceeds from its efficient operating temperature the water is sprayed to the solar panel. The IEC 17025 standard for calibration by the International Electrotechnical Commission was followed.

Measurement Condition	**Thermocouple Type-k Temperature**	**Thermometer Temperature**
Front Solar Panel Surface		
Back Solar Panel Surface		
Ambient		

3.8 Data of Cooling system

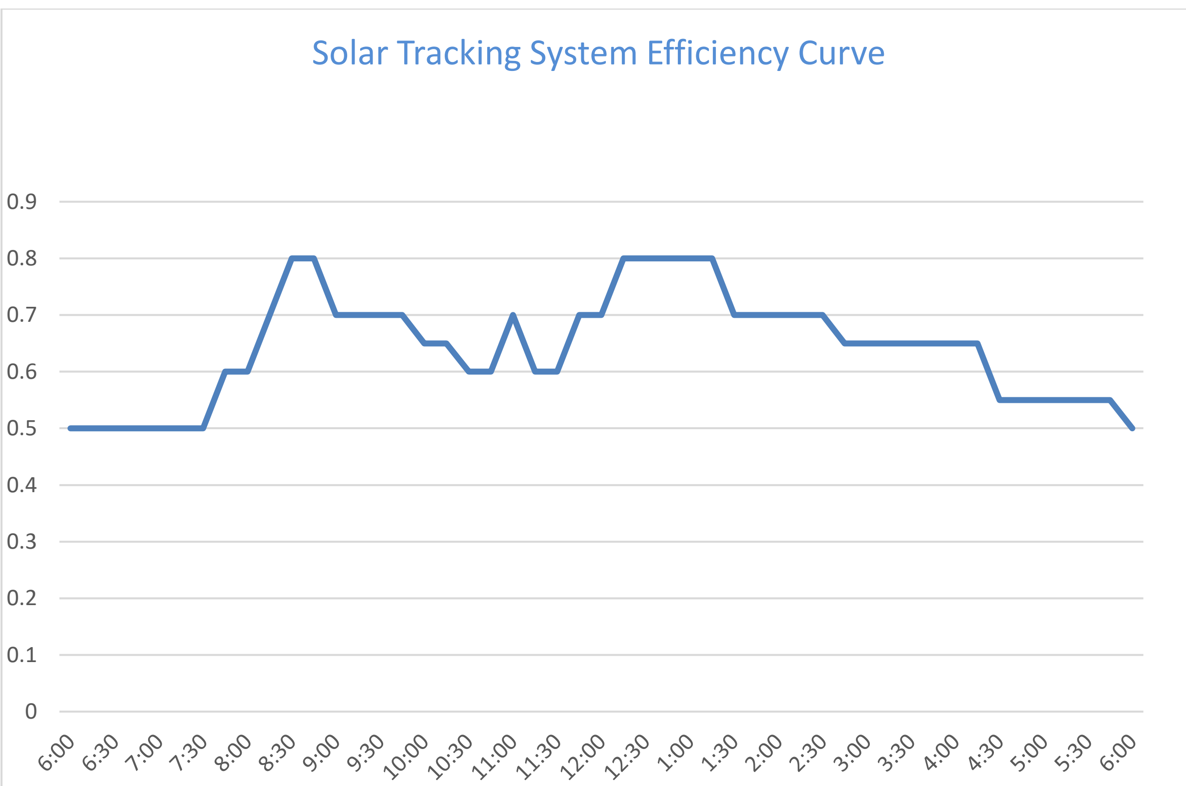
Time	Voltage (V)	Current (A)	Power (W)	Efficiency (%)
6:00				
6:10				
6:20				
6:30				
6:40				
6:50				

Discussion



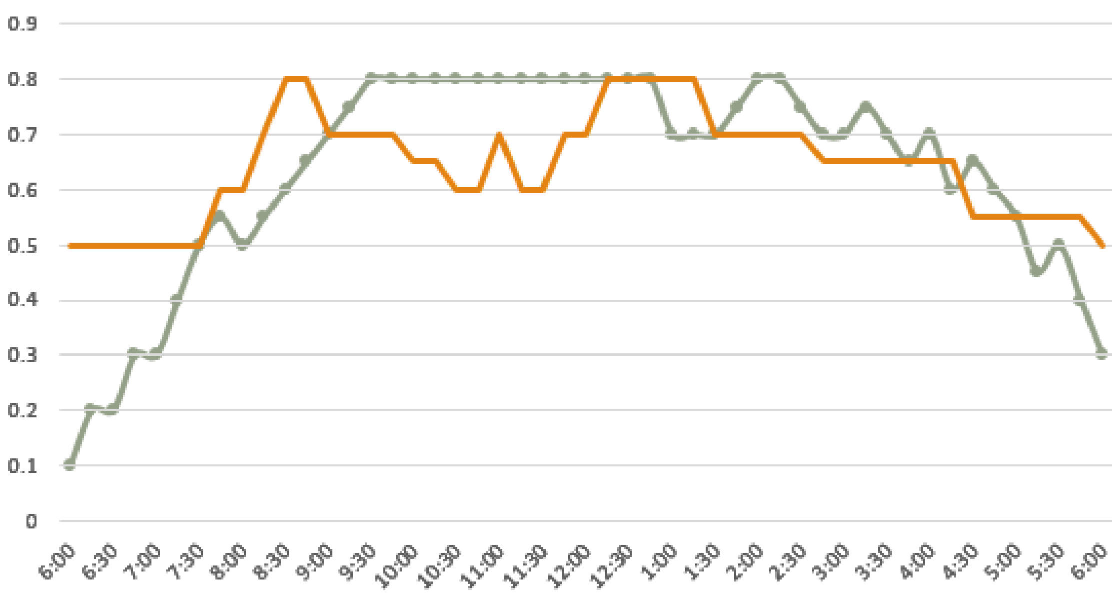
3.9 Data of Sun tracking system

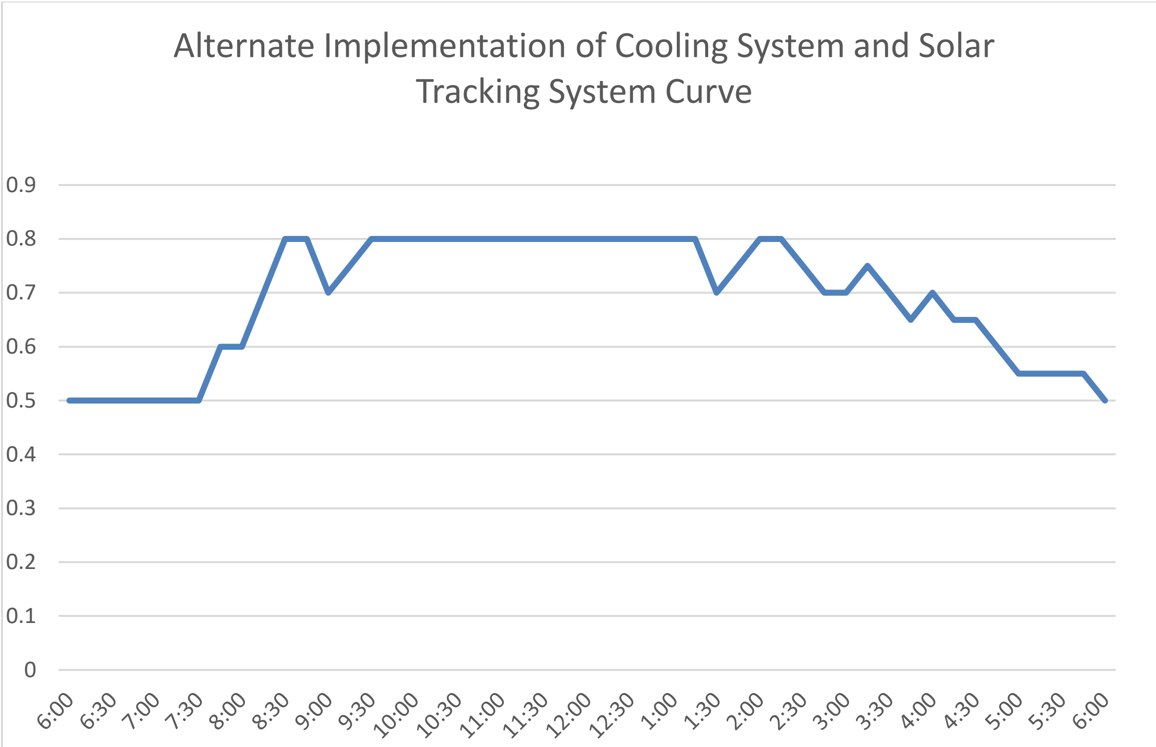
Time	Voltage (V)	Current (A)	Power (W)	Efficiency (%)



3.10 Data of Alternate Implementation of Cooling System and Solar Tracking System

Time	Voltage (V)	Current (A)	Power (W)	Efficiency (%)





By comparing and combining the graphs generated by the two systems, a new efficiency curve can be made that dictates the operation of the proposed system according to the time of day.

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