

Temperature Dependences on Various Types of Photovoltaic (PV) Panel

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Abstract. Temperature is one of the key roles in PV technology performance, since with the increases of temperature the open-circuit voltage will drop accordingly so do the electrical efficiency and power output generation. Different types of Photovoltaic (PV) panels- silicon solar panels and thin film solar panels; mono-crystalline, poly-crystalline, CIS, CIGS, CdTe, back-contact, and bi-facial solar panel under 40°C to 70°C approximately with 5°C interval have been comparatively analyzed their actual performances with uniformly distribution of light illumination from tungsten halogen light source, $\pm 500\text{W/m}^2$. DC-Electronic Load and Data Logger devices with “Lab View” data program interface were used to collect all the necessary parameters in this study. Time needed to achieve a certain degree of temperature was recorded. Generally, each of the panels needed 15 minutes to 20 minutes to reach 70°C. Halogen based light source is not compatible in short wave-length in response to thin-film solar cell. Within this period of times, all the panels are facing a performance loss up to 15%. Other parameters; P_{\max} , V_{\max} , I_{\max} , V_{oc} , I_{sc} , R_{series} , R_{shunt} , Fillfactor were collected as study cases. Our study is important in determining Photovoltaic type selection and system design as for study or industrial needed under different temperature condition.

1. INTRODUCTION

Increasing the performance of the photovoltaic technology has been becoming a main issue of most researchers; increasing the capability of solar cell to absorb more light photons, increasing the life span of the devices, improving its sustainability of heat, and to reduce the cost of the material. There are some ways to do that, such as improving the morphology of the devices, using different method of how to produce the solar cell, inventing a new technology to assist the production of the cell, using



low-concentration technology to reduce the whole system cost, and even using lots of methods to reduce the ambient and panel temperature. To put aside of others perspective, our team in this study was working on the temperature dependence from various material or type of PV panels. Including silicon based solar panel and also thin film solar cell; mono-crystalline, poly-crystalline, CIGS, CIS, CdTe, back-contact, and bi-facial solar panel. Our aim is to provide some informations from all the panels regarding how it works under different temperature condition. But of course to do this, an indoor solar simulator was set up to produce 500W/m^2 of light uniformity through the whole area of the panel. The importance of having an indoor experiment is that for us to control the surrounding condition which will affect the performance of the PV system, such as the light illumination, temperature control, humidity control, etc. Different type of material used on the production of PV panel also affecting not a small portion on the impact. In general, typical PV panel converts only around 20% of the light to electricity and the rest of the incident solar radiation converted to heat ^[1]. Increasing the temperature of the cell modulates the spectral response of the solar cell and the spectral response is found to be dependent with the temperature ^[2].

Photovoltaic (PV) technology behaves differently under different condition; climate, temperature, humidity, irradiance, etc. A rise of temperature module, leads to the decreasing of electrical generating capability of the solar PV panels due to the big reduction of open-circuit voltage, V_{oc} overwhelms the slightly increases in short-circuit current, I_{sc} ^[3]. Andreev et al. ^[7] calculated that the photocurrent increases with the temperature at $0.1\%/^{\circ}\text{C}$ due to the decreasing of the gap of the solar cell and that the open-circuit voltage decreases at $-2\text{mV}/^{\circ}\text{C}$. Many researchers did various kind of experiment to examine the power loss due to the temperature rises. Radziemska and Klugmann ^[4] reported that crystalline based of solar panel facing a reduction of $-0.65\%/^{\circ}\text{C}$, Taguchi et al. ^[5] reported that HIT thin-film cell based hetero-junction structure cell has been reduced from -0.33% to $-0.25\%/^{\circ}\text{C}$ by a new process of manufacturing, and Nishioka et al. ^[6] reported InGaP/InGaAs/Ge triple-junction solar cell having the temperature coefficient of conversion efficiency to be $-0.248\%/^{\circ}\text{C}$, etc ^[8-14]

2. MATERIAL AND METHODS

2.1. Materials and Systems Installation

In this indoor experiment, we were using tungsten halogen bulbs as solar simulator with each bulb being controlled by dimmer. The Dimmers are manually controlled to ensure we get the uniformity out from the bulbs through the whole surface are of panels. Before the experiment began, light radiation was measured by using pyranometer. Our solar simulator was managed to get a uniformity of 500W/m^2 with only 20% miss match at the corner. All parameters were measured by using “DC Electronic Load” and “Data Logger” devices with Lab View program system interface. Thermocouples K type were used to collect the temperature reading.

2.2 Uniformity Light Source Measurement

The intensity was measured by pyranometer. It was tested in 12.5cm gap in each point as the size of the solar cell. Basically, the intensity ready was measured by putting the pyranometer on top of the solar cell in the middle. Red dot is where we put the pyranometer at with 12.5cm gap from each dot to the other as shown in table 1 below. With the 20% of mismatch at the corner area, we still could get a

linear data with panels. All the panels were producing half of its capability to produce electrical power out-put within this table range measurement. Which means the 20% of mismatch at the corner area will not affect much of the performances.

Table 1. Uniformity of light radiation emits by the solar simulator. All the values in the table are in W/m^2 units.

438	500	460	435	423	441
458	500	468	440	430	458
455	500	480	440	440	465
458	500	475	445	440	457
468	510	490	450	435	452
470	514	500	455	436	446
475	510	500	460	440	445
440	440	460	497	500	470
440	470	481	440	425	420

2.3 Experiment Methodology

As all the equipment used at this experiment, here we will describe about the whole work on how the study being progressed. As we mentioned that we are using lots quantity of tungsten halogen bulbs which being controlled by dimmer as light source, hence the panels are basically we put on below perpendicular to the incoming light one by one to be tested. The negative and positive wires from the panels were connected to the DC Electronic Load to receive its current-voltage signal, few thermocouples were attached at the middle, rare and behind of the panels and then connected to the Data Logger device. After the program finished its job to calculate all the parameters we could see the results on the computer screen. Temperature differences between the front middle and back side are in between 5% to 10%, so we decided to take the middle front data as to make a comparative study. The whole picture of this experiment is shown in the figure 1 below.

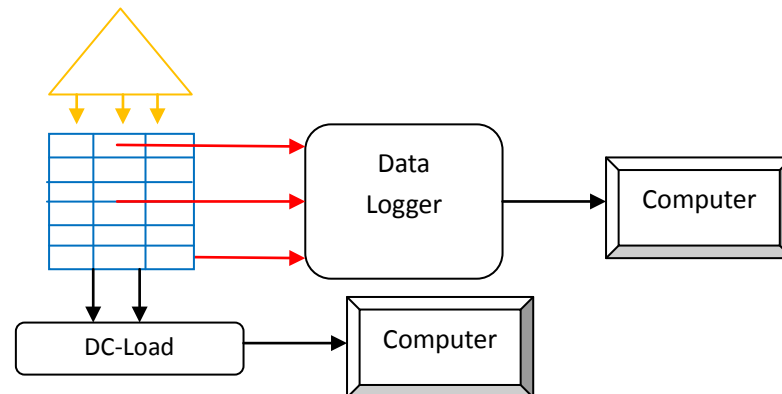


Figure 1. Schematic diagram of how was the experiment being conducted.

Yellow represent the solar simulator, red represent thermocouples, blue represent solar panel.

3. RESULTS AND DISCUSSIONS

Seven different types of solar panels in table 2 are based on crystalline silicon and thin film were used to examine the temperature differences effect on each of the panels, such as mono-crystalline (175W), poly-crystalline (110W and 200W), CIGS (85W), CIS(75W), CdTe (72.5W), back-contact (30W), and bi-facial solar cell (45W).

Table 2. Characterization of solar panels.

Type	Area, m ²	1000W/m ²	500W/m ²	500W/m ²
		Watt Power at 25°C, W _p	Watt Power at 40 °C, W _p	Watt Power at 70°C, W _p
Mono-crystalline	1.31	175	77.97	69.04
Poly-crystalline	0.97	110	48.22	39.81
Poly-crystalline	1.41	200	94.88	84.97
CIGS	0.702	85	42.31	36.27
CIS	0.72	75	44.98	38.69
CdTe	0.613	72.5	20.39	17.89
Back-Contact	0.153	30	15.03	13.35
Bi-Facial	0.12	(Front) 45	20.09	(60°C) 18.59
		(Back) 45	21.21	(60°C) 17.67

A study of how fast the temperature increases with a certain amount of time is important. Some panels were able to reach 75°C after being illuminated by the light radiation for about ± 1200 seconds but some others only able to reach 60°C.

Table 3. Percentage of losses in power, V_{oc} and fill factor in between time to reach 65°C from 40°C.

	Pmax(Watt)	Time(Sec)	% Lost (40°C - 65°C)		
			Wp	Voc	FF
Poly-cystalline	200	780	10.08	12	3.14
Poly-Crystalline	110	1050	10.52	9.92	5.91
Mono-Crystalline	175	950	11.45	12.78	3.58
CIS	75	827	13.98	13.32	2.06
CIGS	85	1281	14.27	5.62	9.79
CdTe	72.5	1183	12.26	plus 2.82	14.82
Back-Contact	30	745	11.18	10.39	6.05
Bi-Facial					
Front	45	1048	11.85	8.94	1.24
Back	45	1350	16.96	10.83	12.73

From the results showed in table 2 and 3, we found that the electrical power generated by our solar simulator was linear to any of the panels except the CdTe panel due to its mismatch to the solar responses of halogen light source. On average, all those panels are losing 10%-15% of its power output after being heated up to 65°C. Every 5°C of temperature raises, each of the panels respond differently; mono(175W) losing ~2%, poly(200W) losing ~2%, poly(110W) losing ~3%, CIGS losing ~2%, CIS losing ~2.5%, CdTe losing ~2%, back-contact losing ~2%, and bi-facial losing ~3%.

Under the same circumstances, thin film based of solar panels were facing a greater power lost than silicon based solar panel. Thin films generally are made of tempered glass on both side which will absorb more heat in a longer time. After being heated up in a longer time, solar panel will greatly reduced its performances. We could conclude that mono-silicon based solar panel is heated faster in compare to bi-facial and thin film solar panel. Open-circuit voltage, Voc is the most affected parameter under different temperature. Voc is the voltage across the sytem when the current is zero. Temperature changes will affect the band-gap of the solar cell^[7]. In our study, we found out that after temperature increased about 30°C which is from 40°C to 70°C, most of the Voc from the panels will decrease by ~10% to ~15%. With this reduction, it is enough to disturb the whole performance of the system. This is also one reason why we are facing a power losses in high temperature condition.

The fill factor as a parameter which shows how the solar panel performs was facing a great negative impact. There were no big impact toward the current flow in the system since the intensity remains stable at 500W/m². While the experiments were conducted indoor under ambient temperature of 21 °C.

4. SUMMARY

Understanding the effect of temperature on to various types of photovoltaic panels will give us a wide picture in industrial, manufacturing, and study field to choose a better PV panel in certain condition. Power lost after being heat up for 30°C is about 15% and 2% reduction in average with 5°C increment of temperature for each panel under a uniform light radiation, stable surrounding condition (indoor experimental study). Halogen light source is not a good choice for Thin-Film based solar cell because

of the band gap and light wavelength and spectrum mismatch. The open-circuit voltage is affected mostly from the temperature changes. Improvement of design and material for the PV panels is important to avoid the power lost due to high temperature.

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