Tilt and the Photoelectric Effect and Its Impact on Solar Power Conversion Efficiency

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***Abstract*— Many factors impact the efficiency of solar panels such as tilt, the question is how and why. Previous research has indicated that there are optimal conditions for solar panels to boost efficiency. However, they do not specify how or why these factors boost efficiency. This study uses solar panels, a multimeter and a protractor to manipulate the tilt of the panels and observe the impact on the efficiency of the panels. It was found that the tilt impacts the path of the energy put into the panel and the efficiency of the panels. The research can be used to observe the photoelectric effect, the impact of tilt on solar panel efficiency and to engineer new technology having to do with solar panel energy conversion.**

***Keywords*— Solar Power, efficiency, energy output, tilt, Photoelectric effect, and solar panels**

I. Introduction

Solar power is a form of renewable energy that takes photons produced from the sun to stimulate electron flow, which is also known as electric current, with a solar panel. Theoretically, solar panels are a good source of energy due to the fact they are clean and use a renewable source. The reality of it is that they are inefficient as they usually only convert about 15-19% of the input to actual electrical power [1]. Many factors influence the efficiency of the solar panels, but this study will focus on how the tilt of the panels influence the efficiency of the solar power conversion. Studies such as Salih et al (2014) have observed the impact of tilt and other factors and output, identifying some of the optimal conditions for the solar panels [2]. While the study can be used to draw the inference of how tilt impacts efficiency, the methodology does not focus on the impacts of tilt itself and that holds true for many other studies as tilt is not the main focus of them. This study will focus on tilt's impact. The study will observe the relationship between the tilt and solar energy efficiency. It will also study the cause of why this happens.

II. Methods

To obtain the measurements of solar input, we used a measurement from a solar energy website that predicts how much solar energy is released per square meter. To obtain the measurement of the output, solar panel cells and a multimeter were used. The tilt was manipulated by measuring the angle of the solar panel to a table under it.

For the procedure, a solar panel would be held adjacent to a protractor and over a table to measure the tilt of the panel. It was plugged into a multimeter that measured the energy produced by the panels. We repeated the process for different angles and found the efficiency through converting the output to watts per meter squared like the input and dividing the output by input.

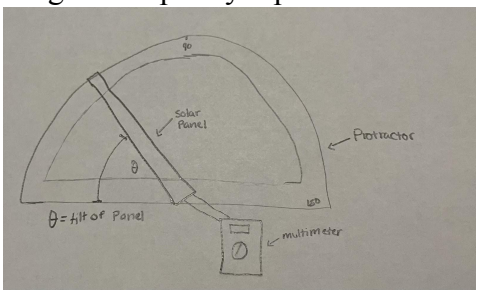

figure 1. A model of the set up used for the procedure

III. Results and discussion

Tilt (Degrees)	Voltage (Volts)	Current (Amps)	Wattage (Watts)	Power Input (w/m^2)	Watts/Meter squared (w/m^2)	Efficiency (%)
15.0	1.42 V	.010 A	.014 w	7020 w/m^2	5.8 x 10^-3 w/m^2	8.3 x 10^-7%
30.0	1.52 V	.010 A	.015 w	7020 w/m^2	6.2 x 10^-3 w/m^2	8.8 x 10^-7%
45.0	1.42 V	.020 A	.028 w	7020 w/m^2	1.2 x 10^-2 w/m^2	1.7 x 10^-6%
60.0	2.12 V	.030 A	.064 w	7020 w/m^2	2.6 x 10^-2 w/m^2	3.7 x 10^-6%
75.0	2.17 V	.090 A	2.0 x 10^-1 w	7020 w/m^2	8.0 x 10^-2 w/m^2	1.1 x 10^-5%
90.0	2.30 V	.010 A	.023 w	7020 w/m^2	9.4 x 10^-3 w/m^2	1.3 x 10^-6%
105.	2.32 V	0.28 A	0.65 w	7020 w/m^2	2.7 x 10^-1 w/m^2	3.8 x 10^-5%
120.	2.34 V	0.36 A	0.84 w	7020 w/m^2	3.5 x 10^-1 w/m^2	5.0 x 10^-5%

135.	2.35 V	0.34 A	8.0 x 10^-1 w	7020 w/m^2	3.3 x 10^-2 w/m^2	4.7 x 10^-5%
150.	2.36 V	0.30 A	0.71 w	7020 w/m^2	2.9 x 10^-1 w/m^2	4.1 x 10^-5%
165.	2.29 V	.010 A	0.23 w	7020 w/m^2	9.4 x 10^-3 w/m^2	1.3 x 10^-6%
180.	1.20 V	.0 A	0 w	7020 w/m^2	0 w/m^2	0%

figure 2. data table showing the tilt of the solar panel, energy output, energy input and efficiency of the solar panel as a result.

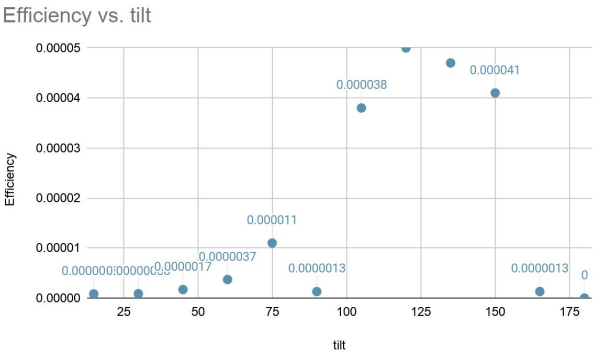

Figure 3. A scatter plot showing the relationship between the tilt of the panel and the efficiency of the panels

The tilt of the panels made a significant impact on the efficiency of the panels. Figure 3, shows that the optimal range for tilt is around 105-135 with a peak at 120.

The electromagnetic radiation entering the panels is made up of photons. The solar panels have a metal grid in them. When the photons hit the metal grid, the photoelectric effect occurs. Photons that hit the metal and electrons come out from a different angle. The photon's energy input is being lost in the form of an electron.

The way the solar panel produces energy is through creating a flow of electrons with incoming energy. The energy input is still the same, but the output is lower due to the lost energy so it will be less efficient.

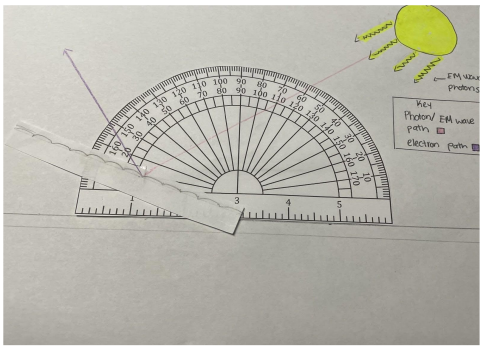

Figure 4. A diagram showing the emitted electron's path after hitting the metal grid of the panel when the panel has a tilt of 15 degrees

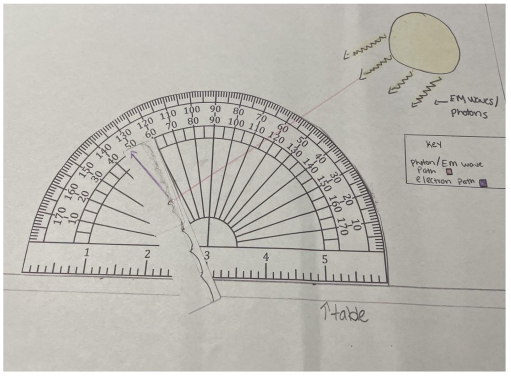

Figure 5. A diagram showing the emitted electron's path after hitting the metal grid of the panel when the panel has a tilt of 120 degrees.

Figure 4 shows this energy loss. It is a visual depiction of the solar energy entering the panels at 15 degrees. According to figure 2, the efficiency of the panel when the tilt is 15 degrees is 8.3 x 10^-7%. This contrasts from the efficiency of the panel at 120 degrees (the optimal tilt) which is much better, 5.0 x 10^-5%. The cause of these differences is the path of the emitted electrons. Figure 5 shows the path of the 'lost' energy. The photon hits the metal grid and the electron leaves the solar cell, but ends up hitting another solar cell that intercepts the path. The energy still enters the panel. More of the energy put into the panel is put to work making the whole process more efficient. This is proven by the difference in numbers in figure 2.

The reason why the efficiency increases then decreases, as seen in figure 3, is because the optimal angles have this same effect. They have tilts that cause the emitted electrons to take similar paths and lead to similar efficiencies.

IV. References

[1] Battersby, Stephen. “News Feature: The solar cell of the future.” *Proceedings of the National Academy of Sciences of the United States of America* vol. 116,1 (2019): 7-10.

[2] J. Breckling, Ed., *The Analysis of Directional Time Series: Applications to Wind Speed and Direction*, ser. Lecture Notes in Statistics. Berlin, Germany: Springer, 1989, vol. 61.