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Effect of Heating Temperature on Indoor Photovoltaics †

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Abstract: The purpose of this research was to investigate the performance of photovoltaic modules when used in different heating temperatures. The heating temperature variants used were room T, TA = 50 °C, TB = 60 °C, and TC = 70 °C. The lamp capacity used was 5 watts with a bulb-type lamp. In addition, the circuit used was a series circuit. This research done on the effect of different temperatures of the heater placed under the photovoltaics showed that when there was an increase in the photovoltaic temperature, the voltage, current, power, and efficiency decreased. Therefore, it is necessary to limit the temperature used for photovoltaics.

Keywords: indoor photovoltaic; heater; series circuit

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1. Introduction

The utilization of solar energy as an environmentally friendly alternative energy source is increasingly in demand by many people. According to research, in the last decade, the level of solar energy usage in Indonesia has continued to increase, reaching 60% [1]. Along with the increasing need for energy, the utilization of solar energy is increasingly enhanced by optimizing the performance of solar panels. The process of converting solar energy into electrical energy is done with the help of photovoltaics (PVs) [2]. However, the disadvantage of photovoltaics is that they are unable to tolerate high temperatures [3]. If the photovoltaics are used at a high temperature, the resulting efficiency will decrease. Overheating caused by an excessive light source and high operating temperature are the main reasons for the low electrical efficiency of photovoltaics [4–6].

Other than this, the weather is an obstacle when using photovoltaics, which results in some circumstances that cause photovoltaics to not work optimally [7,8]. To reduce these problems, a tool was made for indoor photovoltaics, where the tool has a light source from the lamp. This makes the photovoltaics work optimally and stably.

Previous research was conducted by Shafa et al. [9] regarding the effect of light intensity and panel tilt on the convection rate coefficient of a solar water heater. From the results obtained, the higher the light intensity and panel tilt angle, the higher the output temperature. The slope of the panel is influential, namely, by increasing the temperature of the panel.

In addition, Jola et al. [1] researched the performance of series, parallel, and parallel–series relationships of solar panels. The results of the tests carried out show that an arrangement of solar panels with a series relationship is better if the aim is to produce a higher voltage. However, if the goal is to produce a higher current, then the arrangement of solar panels with a parallel relationship is better. In addition, a series–parallel relationship can be used as an alternative if you want to obtain a high enough voltage but with an adequate current.

Another study conducted by Mengata et al. [10] characterized solar photovoltaic modules powered by artificial light to be used as a source for smart sensors. The types of modules used were monocrystalline silicon and polycrystalline modules. Meanwhile, the types of lamps used were CFL, halogen, LED, and incandescent lamps with values of 100–2000 lx, which were evaluated with an uncertainty of ±(3% + 8) lx. The best performance was recorded for the m-Si PV4 module, which achieved a power of up to 555.83 $\mu W/cm^2$ at 2000 lux under incandescent lamps. The lowest performance was recorded for the p-Si PV3 module under LED and CFL lamps, with a power density of only 0.16 $\mu W/cm^2$ at 100 lux.

Based on the results of the research that was done, the purpose of this study was to investigate the performance of photovoltaic modules in indoor photovoltaic testing for different heating temperatures. The heating temperature variants used were room T, TA = 50 °C, TB = 60 °C, and TC = 70 °C. The lamp capacity used was 5 watts with a bulb. In addition, the circuit used was a series circuit. The outputs of this research were the photovoltaic temperature parameters, voltage, current, power, and efficiency.

2. Research Method

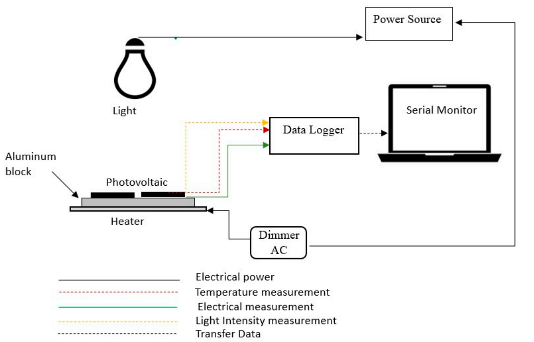
The photovoltaic testing was undertaken with an indoor system using a photovoltaic indoor test tool, as shown in Figure 1. The photovoltaic indoor test tool is a tool used to test photovoltaics in a closed room with lighting using lamp light intensity. This study aimed to investigate the effect of heating temperature on the photovoltaic performance.

Figure 1. Indoor photovoltaic test tool.

The photovoltaic testing process began with the installation of the photovoltaics on the photovoltaic indoor test tool. Figure 2 is a schematic of the photovoltaic performance testing with the photovoltaic indoor test. The photovoltaics were arranged in order from bottom to top, including the heater, aluminum block, and two photovoltaic units arranged in series. In the photovoltaic indoor test tool, this research used a light bulb with a power of 5 watts. The parameters measured included the photovoltaic voltage, photovoltaic current, light intensity, and operating temperature of the photovoltaics. The photovoltaic temperature settings used in this study included room temperature conditions and heating temperatures around 50, 60, and 70 °C. The heating process was carried out by holding at temperatures of 50, 60, and 70 °C for 100 s.

During the testing process, the data logger was activated to collect data on the photovoltaic temperature, photovoltaic voltage, photovoltaic current, and light intensity. The photovoltaic heating used a 240 × 40 mm heating plate with 220 V, as shown in Figure 3. The heating plate was adjusted to the electrical capacity as needed using a dimmer to produce heating temperatures of 50, 60, and 70 °C. In the research results, the room temperature heating temperature is given as T room, as well as TA for 50 °C, TB for 60 °C, and TC for 70 °C.

This study used two photovoltaic units with a monocrystalline type. The two photovoltaic units were assembled in series, as shown in Figure 4. The size of one photovoltaic unit was 110 × 69 mm.



(a)

(b)

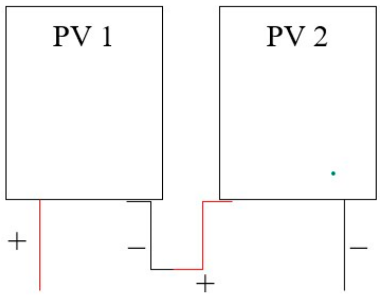
Figure 2. (**a**) Schematic of indoor photovoltaic test; (**b**) real test.

(a)

(b)

Figure 3. (**a**) Aluminum block; (**b**) heater.

(a)



(b)

Figure 4. (**a**) Real test; (**b**) schematic of indoor photovoltaic test.

Data were collected using Arduino Uno to control the voltage and current sensors, temperature sensor, and light intensity sensor. The voltage and current sensors used were MAX 471, Kuongshun Electronic, Shenzhen, China. The temperature was measured using a thermocouple with a MAX 6675 sensor, Kuongshun Electronic. The light intensity sensor used a light intensity LDR. Data from these sensors were collected on an Arduino Uno data logger. The data collected on the Arduino was displayed on a serial monitor.

Photovoltaics can produce electrical energy from the conversion of light intensity in the photovoltaics. The light intensity causes the movement of electrons in the photovoltaics to produce a direct electric current. To find out the electrical power generated by PVs, we can use the following formula:

$$P = V \times I$$

where P is the power produced by the photovoltaics, V is the voltage of the photovoltaics, and I is the electric current. The photovoltaic efficiency is the ratio between the power generated and the energy of the light intensity:

$$\eta = \frac{P}{I_r \cdot A} \times 100\%$$

where η is the photovoltaic efficiency, I_r is the light intensity, and A is the cross-sectional area.

3. Results and Discussion

The following presents the results of the tests that were carried out with the heating temperature variants: T room, TA, TB, and TC.

From Figure 5, the test results show that the highest voltage was found at the temperature T room, with a value of 1.760 V, while the lowest value was found at the heating temperature TC, with a value of 1.515 V.

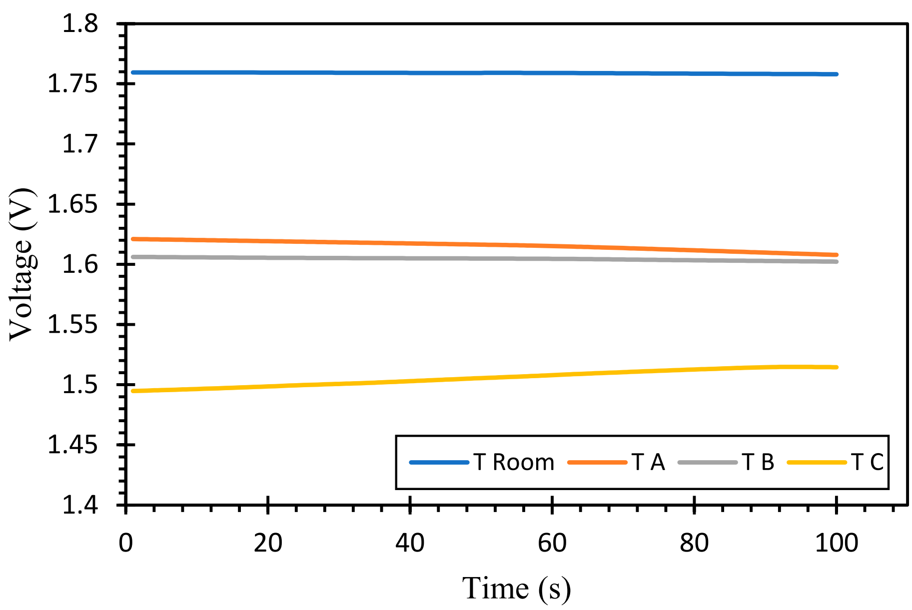


Figure 5. Voltage against time graph.

The current graph in Figure 6 shows that the temperature T room produced the highest value of 1.095 A, while the lowest value was produced at heating temperature TC, amounting to 0.862 A.

The power graph in Figure 7 shows that the temperature T room produced the highest value of 1.929 W, while the lowest value was produced at heating temperature TC, with 1.317 W.

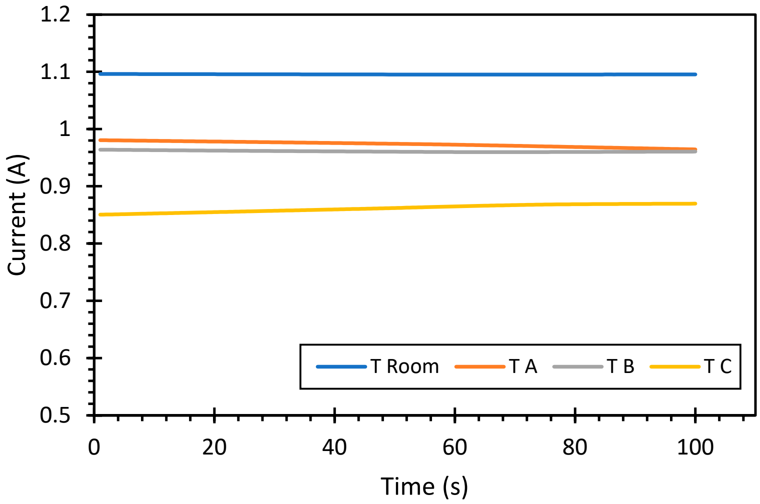


Figure 6. Current against time graph.

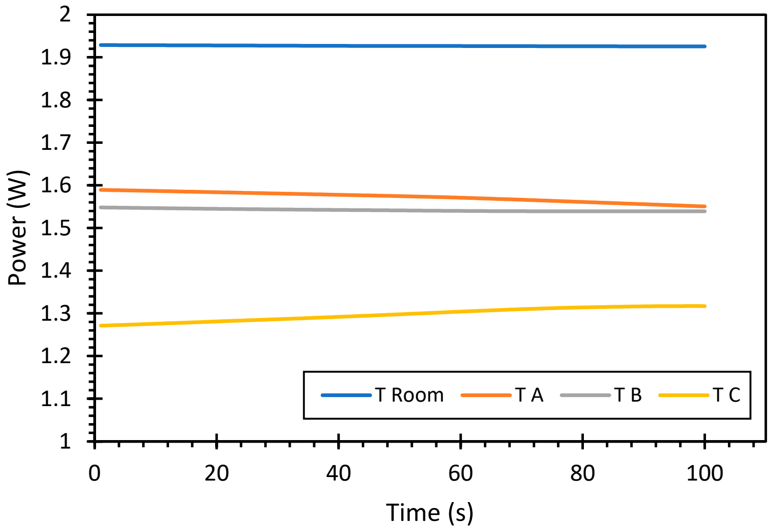


Figure 7. Power against time graph.

Figure 8 shows that the highest efficiency was found at the temperature T room, with 0.00012691%, while the lowest was at the TC heating temperature, with 0.0000902%.

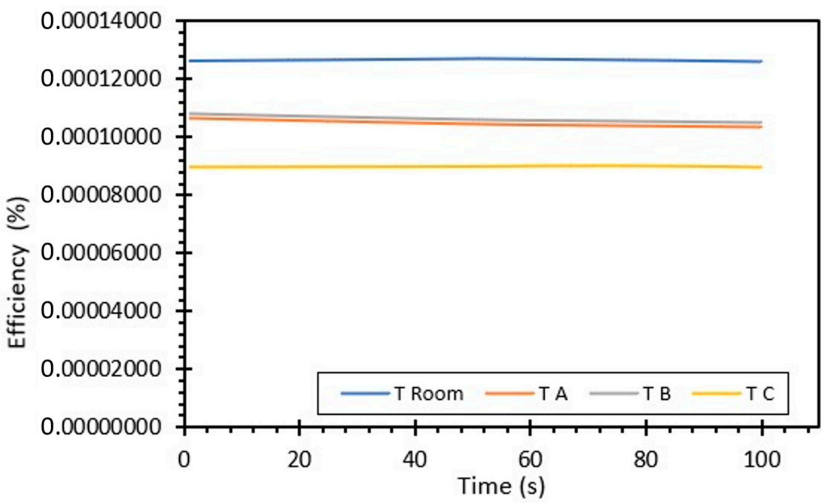


Figure 8. Efficiency against time graph.

From the results of the tests that were carried out, including voltage, current, power, and efficiency tests, all the results showed that the heating temperature T room produced the highest values, while the heating temperature TC produced the lowest values. This happened because temperature is very influential on photovoltaic efficiency. This agrees with research conducted by Dhassa et al. [4], which explained that an increase in the photovoltaic temperature causes a decrease in the efficiency of the current (A) and voltage (V) of the electrical output.

4. Conclusions

This research that was done on the effect of the temperature of the heater placed under the photovoltaics (room temperature, 50, 60, and 70 °C) showed that an increase in the temperature of the photovoltaics resulted in voltage, current, power, and efficiency decreases. Therefore, it is necessary to limit the temperature used for photovoltaics. In addition, a cooler can be used to reduce the temperature of the photovoltaics.

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