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| **RESEARCH ARTICLE**

Solar Panel Optimization Using Peltier Module TEC1-12706

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| ABSTRACT
One of the renewable energy sources that is presently being developed in Indonesia is the technology that converts solar energy into electrical energy using solar cells or PV panels. The power output of a solar panel is influenced by several factors, including solar radiation intensity, panel surface temperature, shading, and the angle of solar incidence. One factor that can influence the efficiency of a solar panel is the temperature of the solar module. The efficiency of a solar panel decreases as its temperature increases. Installing a Peltier TEC1-12706 on a PV panel will have an impact on heat absorption on the surface of the PV panel, thereby optimizing the power output of the PV panel. This study utilizes three monocrystalline solar panels with a power rating of 50 Wp, which are installed under three conditions: the first solar panel without a Peltier device, the second solar panel with twenty Peltier devices connected in series beside the solar panel, and the third solar panel with twenty Peltier devices connected in series both beside and beneath the solar panel. The output of these solar panels is remotely monitored using IoT as a connection to facilitate the monitoring and control of measured variables, including ambient temperature, solar panel surface temperature, voltage, current, solar panel output power, and efficiency. The data is collected at a height of approximately 12 meters in an outdoor laboratory at the Telecommunications Department of the Electrical Engineering Polytechnic of Sriwijaya Palembang. The measurements are collected between approximately 07:00 to 17:00 local time. The research results reveal that the monocrystalline PV panel with Peltier devices connected in series beneath and beside the solar panel has a higher absorption temperature compared to the solar panel without a Peltier device. Irradiance and ambient temperature have an influence on the voltage and current of the PV panel. The measured irradiance is directly influenced by the ambient temperature. The PV panel, with the addition of Peltier devices beneath and beside it, has an output voltage of 0.3 volts, a higher current value of 0.37 amperes, an increase in output power of 8.9 watts, and an overall average efficiency enhancement of 32.6% compared to the PV panel without a Peltier device.

| KEYWORDS

Energy, PV Panel, Efficiency, Peltier TEC1-12706

| ARTICLE INFORMATION

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1. Introduction
Increasing societal demand for electricity has propelled the rapid development of renewable energy. The need for energy consumption has become increasingly important over time, particularly the demand for electricity, which is common for everyone in their daily activities. Renewable energy refers to energy generated from natural resources that can be continuously replenished (Dinata et al., 2022; Kamal et al., 2021; Ploetz et al., 2016; Syahputra & Soesanti, 2021; Taqwa et al., 2020; Zulakmal et al., 2019).

PV systems are one of the renewable energy sources that can directly generate electricity without causing environmental impacts when subjected to solar radiation. Solar energy has tremendous development potential as a renewable energy source and can serve as an alternative to fossil fuels. Fossil fuels are not environmentally favourable, and their availability is dwindling because they are nonrenewable. Solar energy has become an essential and influential part of human life, particularly in its utilization as a source of electricity (Astanto et al., 2022; Chavan et al., 2021; Fauzih et al., 2021; Garmana et al., 2021; Lupu et al., 2018; Susandi et al., 2021).

The flow of electricity in two metals joined together in a circuit leads to heat absorption at the junction of the metals and heat release at the other junction. When the direction of the current is reversed, the positions of the heat-releasing and heat-absorbing junctions will switch places. The Peltier effect is the name given to Jean's discovery. The Seebeck effect and the Peltier effect serve as the foundation for thermoelectric development (Fatoni et al., 2019; Lupu et al., 2019).

In this study, the idea arose to conduct an experimental analysis of the influence on power output by optimizing the heat on solar panels through the addition of TEC1-12706 Peltier modules

2. Literature Review

Several studies have been conducted, such as "The Effectiveness of Peltier Module Tec-12706 as a Generator by Utilising the Heat Energy from Peltier Module Tec-12706" by Hafidh et al. Tests were conducted with heat producer-to-generator ratios of 2:4, 4:2, and 3:2. The research results showed that all three combinations tested demonstrated the ineffectiveness of the Peltier module TEC-12706 as a generator when utilizing another Peltier module of the same type as the heat producer (AL Fikri, 2016).

Sukma et al. (n.d) studied "The Utilization of Thermoelectric Generators in Solar Power Plants". This study aimed to examine the potential application of Thermoelectric Generators (TEG) in boosting the output voltage of solar panels. The study also aimed to determine the effect of the number of TEG modules on the total voltage produced by the TEG. The study was conducted by installing several TEG modules beneath the solar panel module—the serial connection of seven TEG modules. The voltage produced by the solar panel was derived from solar energy (radiation), whereas the voltage generated by the TEG was derived from solar heat energy. The combination of the voltage generated by the solar panel and the voltage from the TEG is called the hybrid solar energy system voltage. The testing revealed that the hybrid system's voltage was greater than the solar panel voltage, both with 6 TEG modules and 7 TEG modules. With the utilization of 6 TEG modules, an average increase in voltage of 0.60 volts was observed, while with the utilization of 7 TEG modules, an average increase of 0.77 volts was observed (Abadi et al., 2019)

3. Methodology

3.1 Effisiensi PV Panel

A solar panel's maximum output efficiency (η) is defined as the percentage of the optimum output power to the incident light energy used. It can be expressed as:

$$\eta = \frac{P_{out}}{P_{in}} x100 \ldots\ldots\ldots\ldots \quad (1)$$

$$Pin = G.A \ldots\ldots\ldots\ldots \quad (2)$$

η is Solar panel efficiency (%), $Pout$ is Solar panel power output (W), Pin is Solar panel power input (W), G is Radiation (w/m^2) and A is Surface area of solar panel (m^2)

3.2 Experimental Measurements

This study employed three 50Wp monocrystalline PV panels. The PV panels were installed in three different configurations: the first without a Peltier module, the second with a Peltier module installed on the side, and the third with Peltier modules installed both underneath and on the side. The panels were placed at a height of approximately ±12 meters from the ground surface in an outdoor location at the Telecommunication Laboratory Building of the Electrical Engineering Department at Politeknik Negeri Sriwijaya Palembang. The panels were angled 15 degrees, aligned with the floor and connected to an IoT system for monitoring the output voltage, current, ambient temperature, light intensity, and surface temperature. From approximately 7:00 a.m. to 5:00 p.m., this study's experimental measurements or data collection were conducted. Figure 1 illustrates the experimental set up.

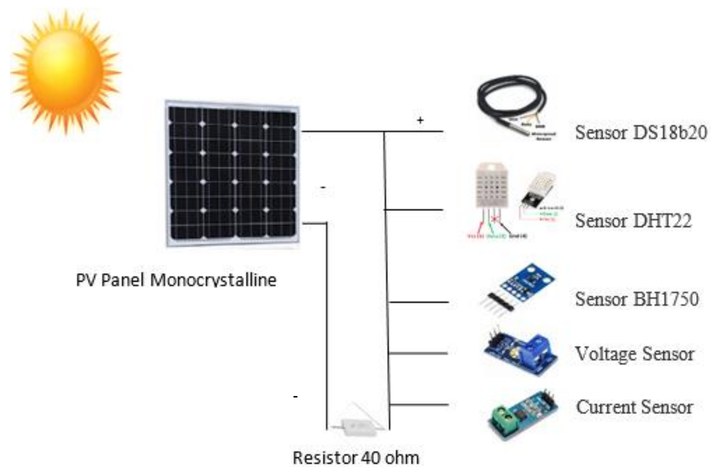


Fig.1. Diagram of Experimental Set Up

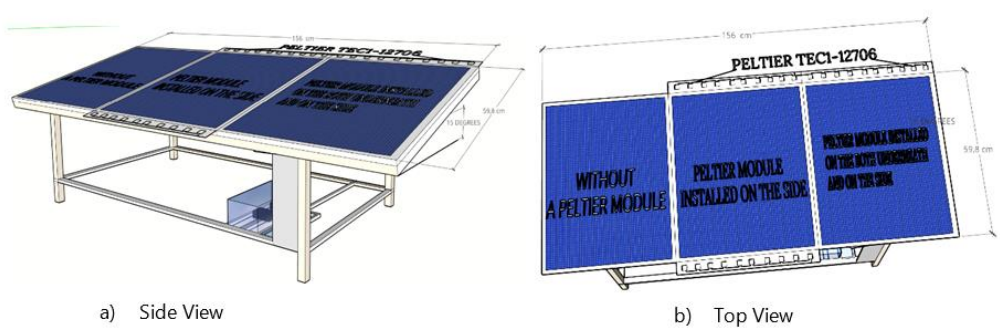
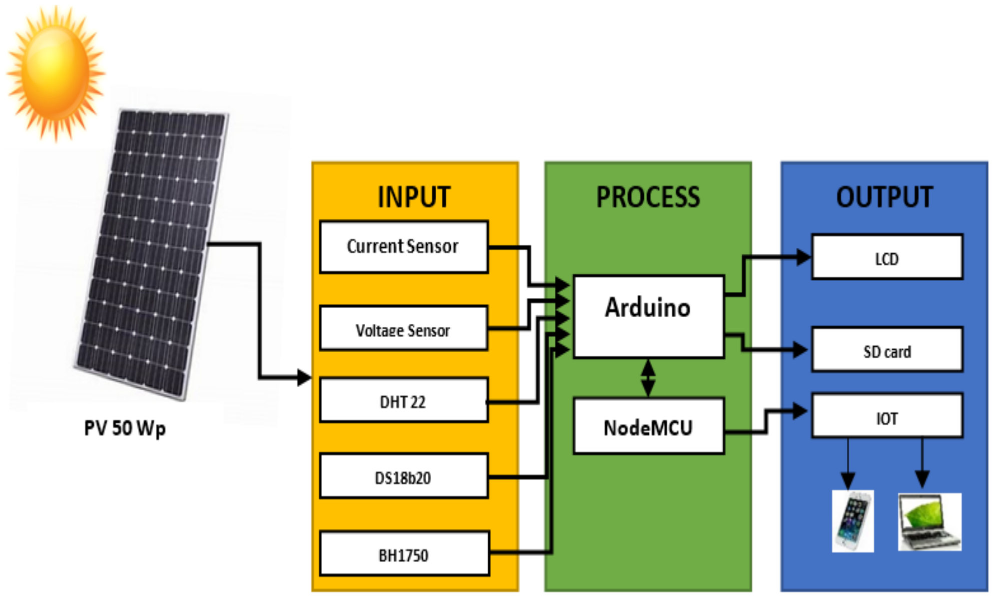


Fig. 2. Schematic of PV Panel (a) Side View, (b) Top View

The aim of this study is to optimize the output power of the PV panel by using a Peltier TEC1-12706 module and implementing IoT as a connectivity solution to facilitate monitoring and control of measured variables, including ambient temperature, PV panel surface temperature, voltage, current, output power, and PV panel efficiency. The electrical output from the PV panel is connected to a voltage sensor for measuring voltage, an additional load in the form of a 40-ohm 20-watt resistor and an ACS712 sensor for measuring current. A BH1750 sensor is used to measure light intensity, a DS18b20 sensor is used to measure PV panel surface temperature, and a DHT22 sensor is used to measure ambient temperature. An Arduino board is employed to analyze the data obtained from the ACS712 sensor, voltage sensor, BH1750 sensor, DS18b20 sensor, and DHT22 sensor. The data is displayed on a 16x2 LCD screen, stored on an SD card, and transmitted to a NodeMCU esp32 board. The NodeMCU esp32 board is responsible for transmitting the data over the internet to the Adafruit IO server as a database and for displaying the data on smartphones, desktops, or laptops. The entire system is depicted in the block diagram shown in Fig. 3



3.3 Spesification of PV Panel

The experiment utilizes three Monocrystalline PV panels with the following specifications:

Table 1. Parameters of PV Panel

Specification	
Model	LM-8050 Pro
Peak Power (Pmax)	50W
Cell Efficiency	16,48%
Max. Power Volt (Vmp)	18.36 V
Max. Power Current (Imp)	2.73A
Short circuit current (Isc)	2.90A
Open circuit volt (Voc)	22.04 V
Power Tolerance	±3%
Max. system voltage	1000V
Series fuse rating (A)	10
Number of bypasss diode	3
Operating temperature	-4°C to 85°C
Maximum system voltage	1000 Vdc
STC: inradiance	1000 W/m2
Module temperature	25°C

3.4 Spesification of Peltier

The experiment used 40 Peltiers with the following specification :

Table 2. Parameters of Peltier

Specification	
Type	TEC1-12706
Operating Voltage	14,4 V Max
Operating Current	6A Max
Power	50-57W
Dimension	40mm x 40mm x 3.9mm
ΔTmax	66 – 75 °C
1.7 Ohm resistance	21.8V
127 thermocouples	±3%
Temperature max	138°C
Min. Operating Temperature	25°C - 50°C

4. Results and Discussion

The first analysis examines the influence of radiation and ambient temperature on the PV panel's temperature. The irradiance, which was directly affected by the ambient temperature, substantially impacts the temperature of the PV panel. Based on the experiment's results, the ambient temperature rose at 9:00 and reached 40.2 degrees Celsius. At 12:00, the photovoltaic system recorded a maximum temperature of 52.56 °C under an irradiance of 431.44 W/m2. By 16:00, the irradiance had progressively decreased to 75.67 W/m2. The average difference in the temperature between the solar energy system with the Peltier TEC1-12706 module mounted alongside and below it and the PV panel without the Peltier module was 2.07°C. The average variance in temperature between the PV panel with the Peltier TEC1-12706 module installed next to it and the PV panel without a Peltier module was 0.4°C.

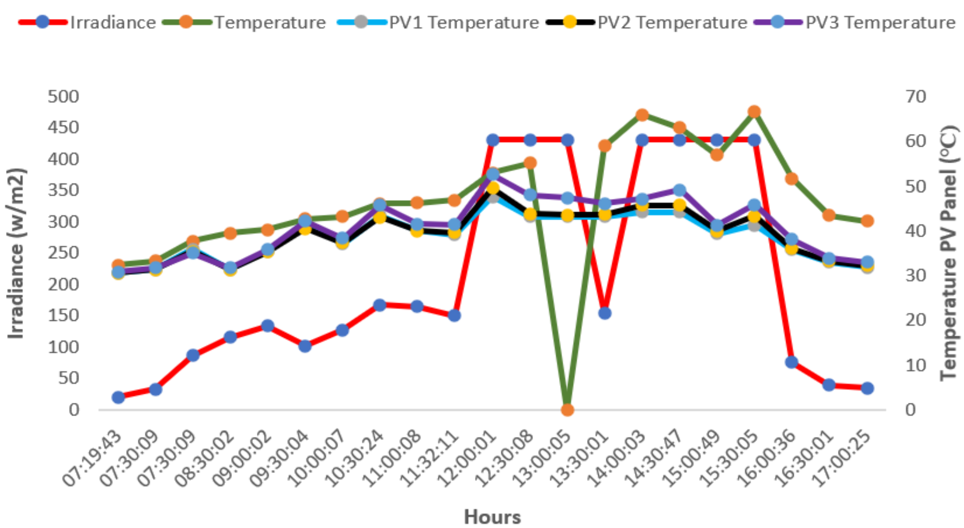


Fig. 4. The Irradiant Effect and Ambient Temperature to PV Panel Temperature

Description **:**
PV1 Temperature: Temperature of the PV panel without Peltier module (℃)
PV2 Temperature: Temperature of the PV panel adjacent to the Peltier module (℃)
PV2 Temperature: The temperature of the PV panel with a Peltier module installed below and next to it (℃)

The output voltage of the PV panels began to increase at 9:00 a.m., as depicted in Figure 5. When the irradiance reached 431.44 w/m2 at 12:00 PM, the output voltage of all three PV panels was the same, which was 23.51 Volts. The average output voltage of the PV panel with Peltier module placed below and beside it was 23 Volts, the average output voltage for the PV panel with Peltier module placed beside was 22.8 Volts, and the average output voltage for the PV panel without Peltier module was 22.7 Volts. The average output voltage increases by 0.3 Volts when a Peltier module is placed below and next to it.

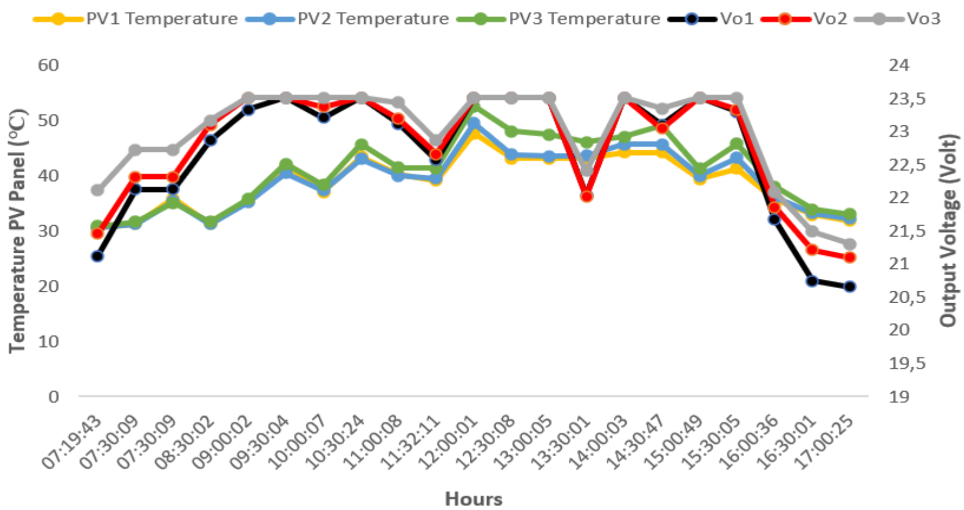


Fig. 5. PV Panel Temperature Effect on Output Voltage

Description :

PV1 Temperature: PV Panel temperature without peltier (℃)

PV2 Temperature: PV Panel temperature with peltier next to it (℃)

PV3 Temperature: The temperature of the PV panel with a Peltier module installed below and next to it (℃)

Vo1: Output voltage without peltier (Volt)

Vo2: Output voltage with peltier next to it (Volt)

Vo3: Output voltage with a Peltier module installed below and next to it (Volt)

To get the current output, add a masonry resistor load of about 40 0hm 20 Watt, using 3 resistors that are connected in series with the IoT circuit and the PV panel. Figure 6 shows the heat difference between the three surfaces of the PV panel, and it does not significantly affect the current output. The average output current is significantly stable. The average output current with the peltier installed bottom and side is 0.52 Amperes, the average output current for the peltier installed on the side is 0.18 Amperes, and the average output current of PV panels without a peltier is 0.15 Amperes. The average output current with a peltier installed at the bottom and side is slightly larger, 0.37 Amperes, compared to the average output current of a PV panel without a peltier.

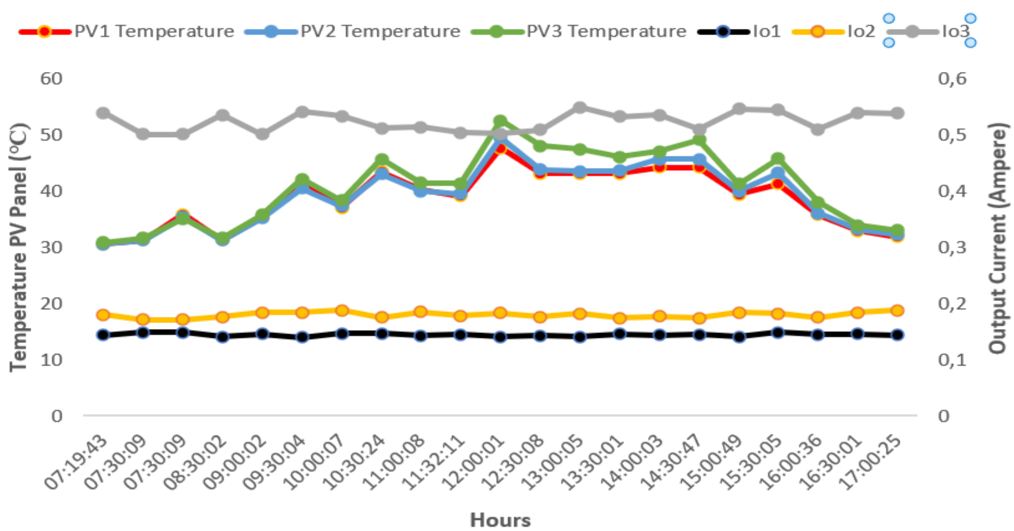


Fig. 6. PV Panel Temperature Effect on Output Current

Description **:**

PV1 Temperature: PV Panel temperature without peltier (℃)

PV2 Temperature: PV Panel temperature with peltier next to it (℃)

PV3 Temperature: The temperature of the PV panel with a Peltier module installed below and next to it (℃)

Io1: Current output without peltier (Ampere)

Io2: Current output with peltier next to it (Ampere)

Io3: Current output with peltier module installed below and next to it (Ampere)

From 8:30 a.m. to 3:30 p.m., as depicted in Figure 7, the power output was relatively stable. During this time range, the average power output of the panel with Peltier module installed below and beside it was 12.26 watts, the average power output of the panel with Peltier module placed beside it was 4.19 watts, and the average power output of the panel without Peltier is 3.34 watts. The average power output of the panel with the Peltier module installed below and next to it had increased by 8.9 watts in comparison to the average power output of the panel without Peltier.

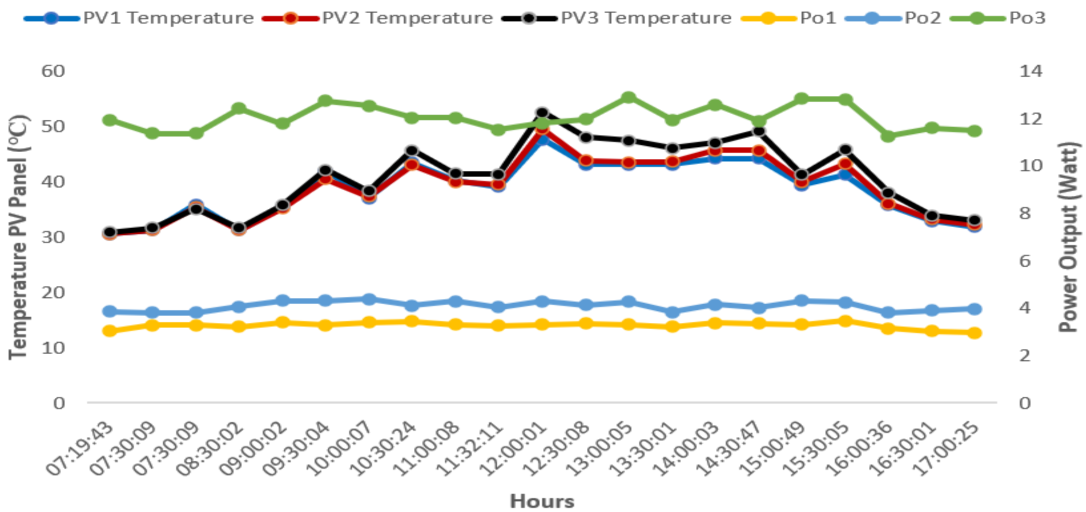


Fig. 7. PV Panel Temperature Effect on Power Output

Description **:**

PV1 Temperature: PV Panel temperature without peltier (℃)
PV2 Temperature: PV Panel temperature with peltier next to it (℃)
PV3 Temperature: The temperature of the PV panel with a Peltier module installed below and next to it (℃)

Po1: Power output without peltier (Watt)
Po2: Power output with peltier placed beside (Watt)
Po3: Power output with peltier placed below and (Watt)

Figure 8 shows that the average efficiency of the PV panel with Peltier module installed below and beside it is 44.6%. The average efficiency of the PV panel with Peltier module placed beside it is 15%, and the average efficiency of the panel without Peltier is 12%. The overall average efficiency increase is 32.6%.

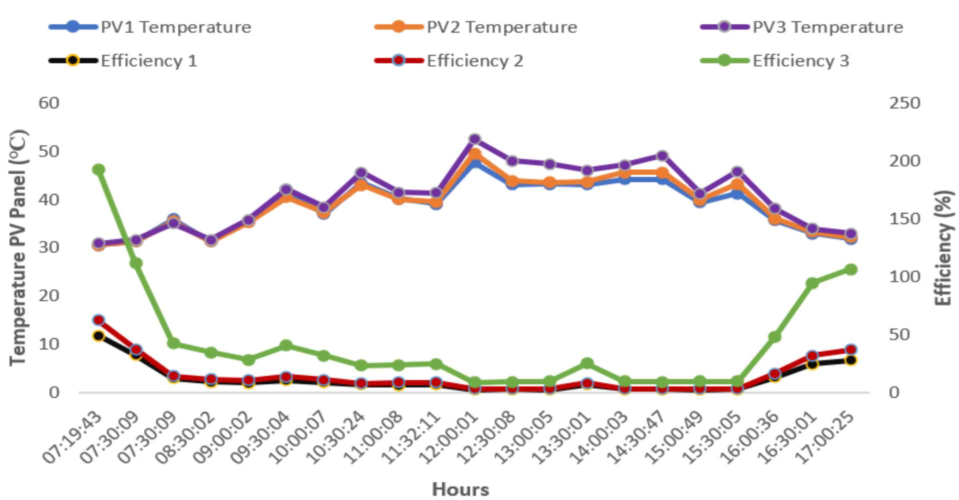


Fig. 8. The Effect of PV Panel Efficiency with Peltier to PV Panel without Peltier

5. Conclusion

The experiments were carried out to determine the performance of the three 50Wp monocrystalline panels and compare the conditions of the three panels to obtain a greater output voltage and efficiency. For the first solar panel without a Peltier, the second solar panel with the addition of twenty TEC1-12706 Peltier modules installed in series beside the solar panel, and the third solar panel with the addition of twenty TEC1-12706 Peltier modules installed in series below and beside the solar panel. The data collection was carried out in the outdoor Telecommunications Laboratory, Department of Electrical Engineering, Sriwijaya State Polytechnic, Palembang, at a height of ±12 meters from the ground surface and an inclination angle of 15 to the floor surface. The experimental results can be seen in the graph that shows irradiance and ambient temperature affect voltage, output power, and efficiency. The current did not significantly affect, and the average current output is stable. The conclusion from this experiment is that the monocrystalline PV panel with the TEC1-12706 Peltier module installed in series below and beside the solar panel has a higher absorption temperature compared to the solar panel installed with the TEC1-12706 Peltier module beside and the solar panel without a Peltier. PV panels with the addition of twenty TEC1-12706 Peltier modules installed in series below and beside the solar panel have a higher output voltage value of 0.3 Volts, a higher current value of 0.37 Amperes, an increased power output of 8.9 watts, an increasing overall average efficiency of 32.6% compared to PV panels without Peltier modules.

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Conflicts of Interest: The authors declare no conflict of interest.
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