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Characteristic Analysis of Solar Panels on Clay and Ceramic Roof Tiles

Abstract. *In general, the PLTS Rooftop installation only considers the power capacity to be installed and the available roof area. It does not consider the type of roof material where it is installed. Meanwhile, the roof of the house has the absorption of sunlight and different thermal properties depending on the type of roofing material. In this study, the objective of this research is to observe the temperature characteristics between solar panels and roofs from 2 types of materials, namely clay tile and ceramic tile, in which the influence of the height between the solar panel and the ceiling on the temperature and its effect on the efficiency of the solar panel. Based on the results of this study, the temperature characteristics between the solar panel and the roof (T3) of various types of material have an influence on the efficiency value of the solar panel, where the maximum efficiency value is obtained for clay tile material at a temperature (T3) of 33.77ºC of 4.22% and ceramic tile at temperature (T3) 33.51ºC at 5.69%.*

Streszczenie. *Ogólnie rzecz biorąc, instalacja PLTS Rooftop uwzględnia tylko moc do zainstalowania i dostępną powierzchnię dachu. Nie uwzględnia rodzaju pokrycia dachowego, na którym jest zainstalowany. Tymczasem dach domu charakteryzuje się pochłanianiem światła słonecznego i różnymi właściwościami termicznymi w zależności od rodzaju pokrycia dachowego. W niniejszym opracowaniu celem tych badań jest obserwacja charakterystyki temperaturowej pomiędzy panelami słonecznymi a dachami z 2 rodzajów materiałów tj. dachówka ceramiczna i dachówka ceramiczna, w których wpływ wysokości pomiędzy panelem słonecznym a sufitem na temperaturę i jego wpływ na wydajność panelu słonecznego. Na podstawie wyników tych badań na wartość sprawności panelu słonecznego wpływa charakterystyka temperaturowa pomiędzy panelem słonecznym a dachem (T3) z różnych materiałów, gdzie maksymalną wartość sprawności uzyskuje się dla materiału z dachówki ceramicznej przy temperatura (T3) 33,77ºC 4,22% i płytka ceramiczna w temperaturze (T3) 33,51ºC 5,69%.* (**Analiza charakterystyki paneli słonecznych na dachówkach ceramicznych i ceramicznych)**

Keywords: PLTS Rooftop, Clay Tiles, Ceramic Tiles, Efficiency.
Słowa kluczowe: dach PLTS, płytki ceramiczne, płytki ceramiczne, wydajność.

1. Introduction

The use of solar energy as an alternative energy source for meeting electricity needs in Indonesia is very appropriate considering the geographical location in the tropics with solar heat available all year round. The natural condition in Indonesia, which is relatively difficult to reach by a centralized power grid chooses solar energy a must [1].

One of the photovoltaic solar energy technologies that are currently being developed is the Solar Power Generation technology on the roof of the building or PLTS Rooftop. PLTS Rooftop is a reliable solution for energy supply [2]. Some of the advantages of the PLTS Rooftop system include that it is easy and cheap to integrate with existing electrical systems and can reduce the burden on the existing system network. Besides, it is easy to maintain and operate but has a significant impact on reducing pollution and the greenhouse effect [3].

Seeing that the potential for solar energy in Indonesia is enormous [4], several studies on the use of PLTS Rooftop include [5] discussing the possibility for implementing rooftop solar power plants in campus buildings. [6] researched the design of rooftop off-grid solar panels in residential homes as an alternative source of electrical energy. [7] investigated strategies for the application of solar cells (photovoltaic cells) to residential and commercial buildings. [8] discusses the application of rooftop solar power plants to reduce electricity consumption during peak load conditions. [9-11] discusses the implementation of PLTS rooftop in buildings.

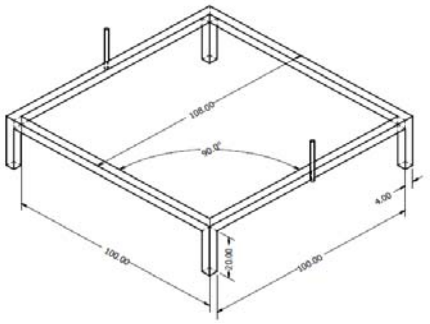
In general, the installation of PLTS Rooftop only considers the power capacity to be installed [12], and the available roof area. It does not consider the type of roof material where it is installed. Meanwhile, the roof of the house has the absorption of sunlight and different thermal properties depending on the type of roofing material. The research that has been done to determine the effect of temperature on roof coverings includes [13], [14], and [15]. [13] nvestigated the thermal conditions of roof space resulting from various types of roofing materials such as tile, asbestos and zinc. The results of this study indicate that the average temperature of the roof space on the roof tiles is 1.91ºC to 2.31ºC lower than that of asbestos and zinc roofs. Tile roofs are also better able to withstand solar radiation. The average value of the surface temperature of the tile roof was 0.28 °C lower than the surface temperature of the asbestos roof and 1.55 °C lower than the surface temperature of the zinc roof. However, the average temperature profile of the lowest roof surface during the day on the asbestos roof is 38.71ºC. Research conducted by [14] discusses the manufacture and testing of tools to determine the conductivity of zinc plate, multi roof, and asbestos. The results showed that the highest conductivity value was found on the zinc plate (0.482 W/m°C), and the lowest conductivity value was multi roof (0.132 W/m°C). [15] researched the Effects of Solar Photovoltaic Panels on Roof Heat Transfer. [15] discussed roof temperatures below PV 2.5 times more relaxed than roofs exposed to sunlight.

Several related studies such as [16], which discussed the thermal characteristics of PV rooftop installations. Several previous studies have discussed the effect of the type of roof material used as a place for installing PLTS Rooftop on the temperature between the solar panels and the roof and have not examined the effect of the distance between the solar panels and the type of roof material on the temperature of the solar panels and have not discussed its impact on the efficiency of the solar panels. Based on this description, this study was made to observe the temperature characteristics between solar panels and roofs of clay and ceramic tile materials. In this research, we will keep the effect of the distance between the solar panels and the roof on the temperature and the impact on the efficiency of the solar panels.

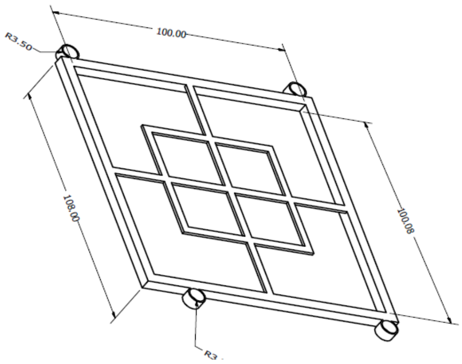
2. Methods

II.1. Research Instrument Design

For the solar panel mount frame, hollow iron material measuring 4 x 4 cm is used and also angled iron measuring 3 x 3 cm. Acrylic material is used for the material on the load panel. Figure 1 below shows the design of the solar panel frame and roof.



(a)



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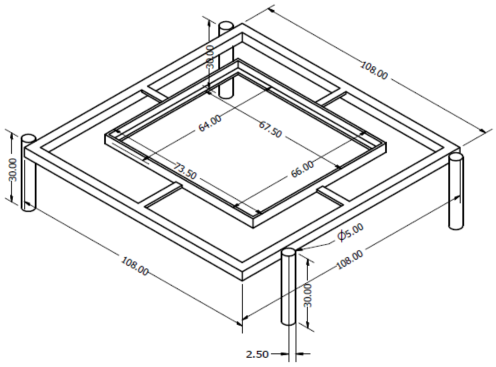

(c)

Fig 1. (a). Solar Panel Mount Design, (b). Tile Mount Design, (c) Dimensions of Solar Panel and Roof Frame

In designing the load panel as the output of the solar panel, the acrylic material is used with a size of 75 x 60 cm. The following figure 2 shows the research instrument placement design.

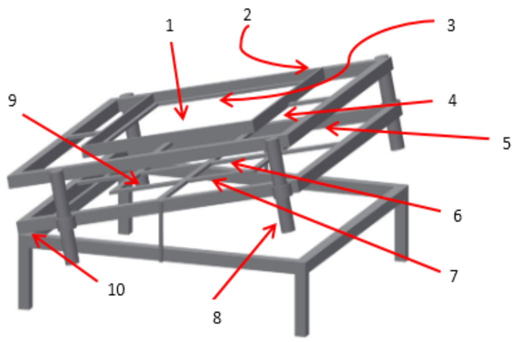

Fig 2. Research Instrument Placement Design

Information:
1. Solar Panel Mount
2. Place Solar Simulator
3. Temperature over solar panel, T_1 (℃)
4. Temperature under solar panel,, T_2 (℃)
5. Temperature between solar panel and roof, T_3 (℃)
6. Temperature on the roof, T_4 (℃)
7. Temperature under the roof, T_5 (℃)
8. Distance Variation Controller (cm)
9. Roof Mount
10. Tilt Angle (°)

Fig 3. Data Retrieval Process

II.1. Testing Procedure

After the process of manufacturing and installing the research components is complete, it is followed by the testing procedure. The steps in the testing procedure are as follows:
1. The test will be carried out at 09.00 until 15.00 local time.
2. Adjust the angle of the solar panels based on the type of roof used.
3. Installing solar panels on the roof material with a distance of H1.
4. Measure the distance (cm) between solar panels and the roof being used.
5. Take temperature measurements on top of the solar panel (℃) and the temperature between the solar panel and the roof (℃) using the TC-O8 Thermocouple Data Logger.
6. Measuring the amount of solar radiation (W / m2) on a solar panel using a Solar Power Meter SPM-1116SD measuring instrument.
7. Connect the solar panel output to the load panel and turn the toggle switch ON.
8. Connect a Datalogger Voltmeter and Ammeter with a laptop to observe the amount of current and voltage on the solar panel.

➢ To ensure that the datalogger and measurement instruments on the load panel are functioning correctly, it can be determined by turning ON the switch on the lamp, then increasing the voltage by turning the potentiometer, in this case, the dimmer to its top condition. The brightness of the lamp will be directly proportional to the amount of current and voltage and the intensity of the sun received by the solar panel. After all, measuring instruments are functioning correctly, then data retrieval can be carried out.

9. Procedure 1 to 9 is repeated with H2 and H3 intervals.
10. Procedures 1 to 10 are repeated for zinc roofs, clay tiles, ceramic and metal tiles.

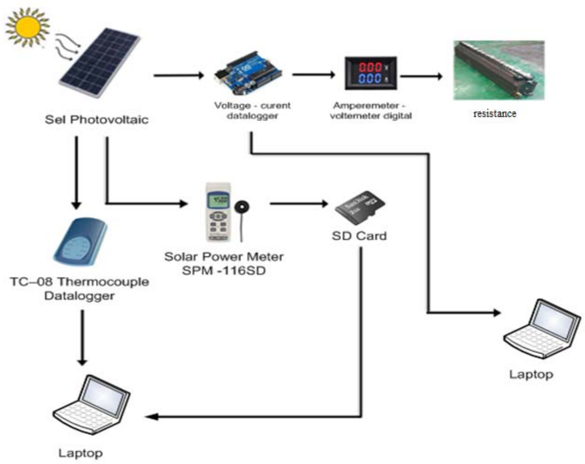

Fig 4. Schematic of PLTS Rooftop

3. Results and Discussion

The research data contains solar panel parameters measured on different types of roofing materials, namely clay tile and ceramic tile. For every kind of roof, the measurement data is also detailed in the various sizes of solar panels and roof distances, covering a distance of 35 cm, 30 cm, 25 cm, and 20 cm. In the variation of length, the research was conducted at 3 (three) observation times, namely at 09.30 WITA, 12.30 WITA, and 14.30 WITA.

The measurement data needed in this study include:

- Solar radiation, G_{bt} (W/m^2)
- Temperature over solar panels, T_1 (℃)
- Temperature under solar panel, T_2 (℃)
- Temperature between solar panel and roof, T_3 (℃)
- Temperature on the roof, T_4 (℃)
- Temperature under the roof, T_5 (℃)
- Solar panel current, I (A).
- Solar panel voltage, V (V)
- Time, (WITA)

The following is research data from each of the above categories, which is taken from the average value of the measurement results.

III.1. Characteristics of I-V on Clay Tiles

Figure 4 shows the characteristics of the I-V curve with various variations in the distance of the solar panels on clay tiles for the first experiment. In this graph, it can be seen that the voltage generated by the solar panel is inversely proportional to the amount of current flowing, where the more significant the voltage, the smaller the current. This is influenced by the resistive load (shear resistance) used in this experiment which is varied from the maximum value to the minimum value for each variation of the distance between the solar panels and clay tiles. At a distance of 25 cm and 20 cm, it appears that the voltage value increases along with the decreasing current value, but when the voltage reaches a value of 21 V and a current value of 0.21 A for a distance of 20 cm and 0.25 A for a distance of 25 cm, it can be seen that The graph trend changes a little which is not too significant due to the value of the voltage while the current changes with a relatively small value. The greatest voltage value is generated at a distance of 30 cm, which is 22.29 V with a current value of 0.21 A.

Based on Figure 5, the battery charging work area is shown as an output on a solar panel controlled by a BCR (Baterry Control Regulator). BCR is a battery charging controller circuit in a solar cell system by regulating the voltage used to charge the battery at a voltage range of 11.4 V to 14.5 V as shown in the graph above for charging a 12 V. If the voltage drops to 11.4 V, the controller will charge the battery when the sun is hot, but at night, the controller will cut off the supply of electrical energy. If the voltage rises to 14.5 V, the controller will stop charging the battery. The excessive voltage on the battery will result in relatively short battery life.

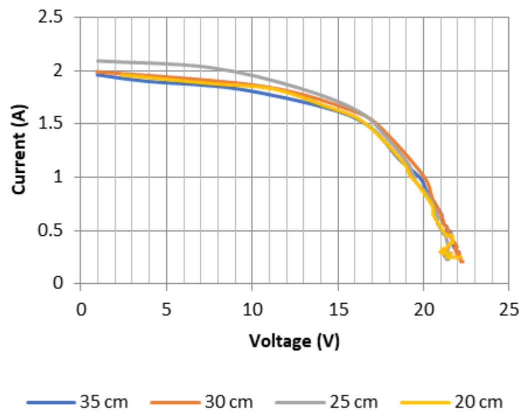

Fig 5. Characteristics of I-V Curves with Various Variations of Solar Panel Spacing on Clay Tiles for the First Experiment

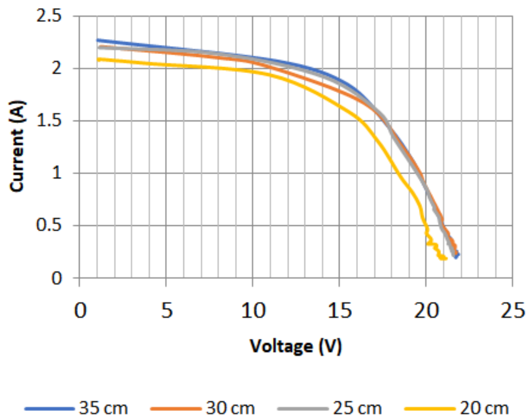

Fig 6. Characteristics of I-V Curves with Various Variations of Solar Panel Spacing on Clay Tiles for the Second Experiment

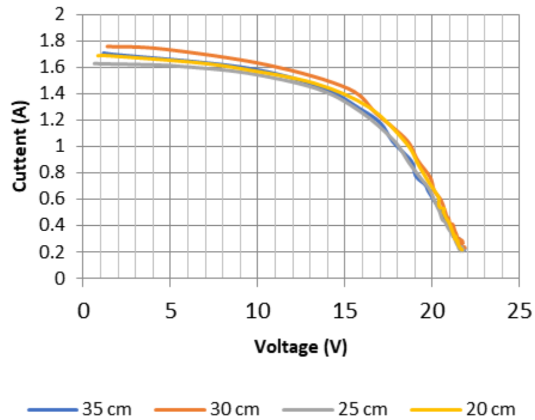

Fig 7. Characteristics of I-V Curves with Variations of Solar Panel Spacing on Clay Tiles for the Third Experiment

Based on Figure 6 above, shows the characteristics of the I-V curve with various variations in the distance of the solar panels on clay tiles for the second experiment. In this graph, it can be seen that the voltage generated by the solar panel is inversely proportional to the amount of current flowing, where the more significant the voltage, the smaller the current. This is influenced by the resistive load used in this experiment which is varied from the maximum value to the minimum value for each variation in the distance between the solar panel and clay tile. From the graph trend, it can be seen that at a distance of 20 cm, the current and voltage have a minimum value when compared to the resulting current and voltage values at a distance of 25 cm, 30 cm and 35 cm. This is because the effect of convection heat transfer between solar panels and clay tiles at a distance of 20 cm is greater because this experiment is carried out when solar radiation is at its maximum value (daylight).

Based on the graph above, it can be seen that the largest voltage value is generated at a distance of 35 cm, which is 21.75 V with a current value of 0.21 A. In the graph above, the battery charging work area is shown as an output on a solar panel controlled by BCR.

Based on Figure 7, shows the characteristics of the I-V curve with various variations in the distance of the solar panels on clay tiles for the third experiment. In this graph, it can be seen that the voltage generated by the solar panel is inversely proportional to the amount of current flowing, where the greater the voltage, the smaller the current. On the graph, it can be seen that the voltage values at each variation of the distance of 35 cm, 30 cm, 25 cm, and 20 cm tend to follow the changes in the resulting current values. The largest voltage value generated in this experiment is at a distance of 35 cm with a voltage of 21.85 V and a current of 0.23 A. Based on Figure 7, the battery charging work area is shown as output on a solar panel controlled by BCR.

III.2. Characteristics of I-V on Ceramic Tiles

Figure 8 shows the I-V characteristics with variations in the distance of the solar panels on the ceramic tile for the first experiment. In this graph, it can be seen that the voltage generated by the solar panel is inversely proportional to the amount of current flowing, where the greater the voltage, the smaller the current. This is influenced by the resistive load used in this experiment which is varied from the maximum value to the minimum value for each variation in the distance between the solar panel and ceramic tile. It appears that the largest voltage value is obtained at a distance of 30 cm, which is 22.09 V with a current value of 0.25 A.

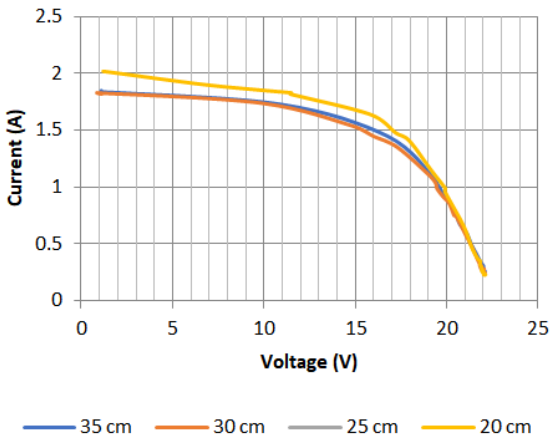

Fig 8. Characteristics of I-V Curves with Various Spacing of Solar Panels on Ceramic Tiles for the First Experiment

Based on Figure 8 above, the battery charging work area is shown as the output on the solar panel which is controlled by the Baterry Control Regulator.

Figure 9 shows the characteristics of the I-V curve with various variations in the distance of the solar panels on the ceramic tile for the second experiment. In the graph above, shows the characteristics of the I-V curve with various variations in the distance of the solar panels on the ceramic tile for the first experiment. In this graph, it can be seen that the voltage generated by the solar panel is inversely proportional to the amount of current flowing, where the greater the voltage, the smaller the current. This is influenced by the resistive load used in this experiment, which is varied from the maximum value to the minimum value for each variation in the distance between the solar panel and ceramic tile. The largest current value is obtained at a distance of 30 cm, which is 23.8 V and the maximum voltage value is generated at a distance of 20 cm, which is 22.27 V with a current value of 0.23 A. Based on the graph above, the battery charging work area is shown as output on solar panels controlled by the Baterry Control Regulator.

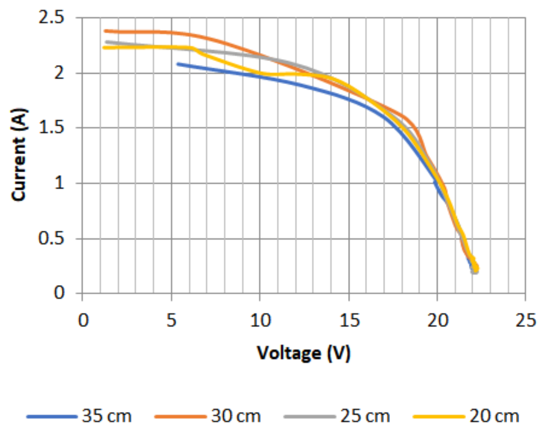

Fig 9. Characteristics of I-V Curves with Various Spacing of Solar Panels on Ceramic Tiles for the Second Experiment

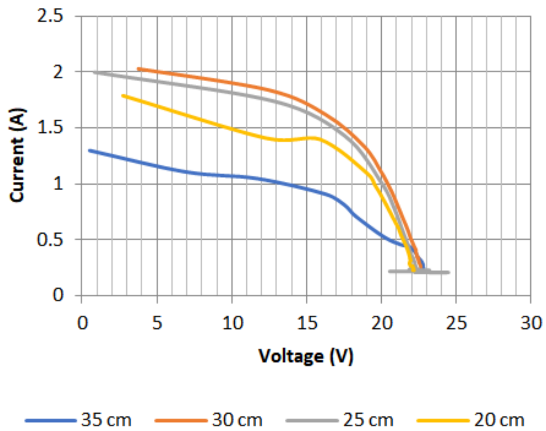

Fig 10. Characteristics of I-V Curves with Various Spacing of Solar Panels on Ceramic Tiles for the Third Experiment

Figure 10 shows the characteristics of the I-V curve with variations in the distance of the solar panels on the ceramic tile for the second experiment. In the graph above, shows the characteristics of the I-V curve with variations in the distance of the solar panels on the ceramic tile for the first experiment. In this graph, it can be seen that the voltage generated by the solar panel is inversely proportional to the amount of current flowing, where the greater the voltage, the smaller the current. This is influenced by resistive loads. In the experiment of 25 cm, 30 cm, and 35 cm, it can be seen that the graph trend is constant where the values of current and voltage change with changing values of resistive resistance. Whereas at a distance of 20 cm, when the current is 0.99 A, the voltage increases slightly by 0.47 V. The largest voltage value in this third experiment is obtained when the distance is 35 cm with a value of 22.80 V. battery charging work area as output to the solar panel which is controlled by the Baterry Control Regulator.

III.3. Solar Panel Temperature Characteristics

Figure 11 shows a comparison of temperature characteristics for several distance variations in the type of clay tile material. The test using the type of clay tile material showed that at a distance of 35 cm, the highest T3 temperature in the test using clay tile roofing material was obtained in the test carried out at 09.30 WITA, which was 33.7°C. Next, in the test with a distance of 30 cm, the highest T3 temperature was obtained in the test carried out at 09.30 WITA, which was 35.9°C. Next, in the test with a distance of 25 cm, the highest T3 temperature was obtained in the test conducted at 09.30 WITA, which was 36°C. Next, in the test with a distance of 20 cm, the highest T3 temperature was obtained in the test carried out at 12.30 WITA, which was 38.5°C, this result was slightly different from the test result at 09.30 which was 38.2°C. Table 1 shows the results of testing the characteristics of solar panels on clay tiles.

TABLE I Comparison Of Temperature Characteristics Of Clay Tiles

Distance (cm)	Time (WITA)	G_{bt} (W/m^2)	T_1 (℃)	T_2 (℃)	T_3 (℃)	T_4 (℃)	T_5 (℃)
35	09.30	794.8	57.59	43.68	33.77	40.72	38.55
	12.30	1019	40.24	37.84	25.97	31.56	30.01
	14.30	695.8	36.22	28.07	30.52	33.68	29.79
30	09.30	839.7	58.13	45.30	35.90	40.99	40.02
	12.30	1006	44.09	39.82	33.10	38.36	30.81
	14.30	694.8	42.53	37.19	27.18	34.50	29.34
25	09.30	761.4	55.85	36.68	36.00	40.72	39.63
	12.30	996	40.22	38.58	23.60	35.90	21.53
	14.30	683.2	42.32	28.76	28.28	37.87	35.00
20	09.30	855	57.05	37.00	38.32	40.90	40.08
	12.30	991.9	38.50	26.04	24.69	39.64	34.69
	14.30	678.8	42.32	28.76	28.28	37.87	35.00

TABLE II. Comparison Of Temperature Characteristics Of Ceramic Tiles

Distance (cm)	Time (WITA)	G_{bt} (W/m^2)	T_1 (℃)	T_2 (℃)	T_3 (℃)	T_4 (℃)	T_5 (℃)
35	09.30	772	43.92	40.52	30.01	33.68	30.81
	12.30	1014	60.51	57.67	33.07	36.45	34.48
	14.30	649	49.49	48.55	34.55	40.08	38.70
30	09.30	780.3	44.12	40.48	30.74	36.22	34.88
	12.30	996.6	64.65	60.52	33.46	37.00	35.63
	14.30	800.7	49.09	48.46	33.64	40.13	37.49
25	09.30	784	46.24	41.87	33.46	35.90	34.23
	12.30	940	64.91	61.19	34.03	36.89	35.81
	14.30	801	48.62	47.22	33.51	40.18	39.05
20	09.30	799.4	46.75	44.59	33.62	37.00	35.13
	12.30	1032	60.66	56.58	34.44	36.25	35.75
	14.30	737.1	48.33	46.97	35.88	40.02	37.74

The next temperature characteristic test is for ceramic tile material, with several variations of the distance. In the test using the type of ceramic tile material, it shows that at a distance of 35 cm, the highest T3 temperature in the test using clay tile roofing material was obtained in the test carried out at 14.30 WITA, which was 34.55°C. Next, in the test with a distance of 30 cm, the highest T3 temperature was obtained in the test carried out at 14.30 WITA, which was 33.64°C. Next, in the test with a distance of 25 cm, the highest T3 temperature was obtained in the test which was carried out at 12.30 WITA, namely 34.03°C. Next, in the test with a distance of 20 cm, the highest T3 temperature was obtained in the test carried out at 14.30 WITA, which was 35.88°C. Table 2 shows the results of testing the characteristics of solar panels on ceramic tiles.

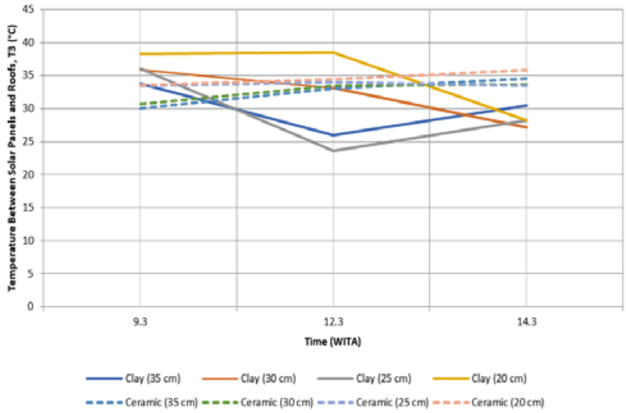

Fig 11. Comparison of temperature characteristics for clay and ceramic tile types

Testing the temperature characteristics of the solar panels on clay tiles showed a trend of decreasing temperature graphs from 09.30 to 14.30. On the other hand, in the ceramic tile material testing, the temperature graph trend increased from 09.30 to 14.30. This is because clay tile is a bad conductor so that the heat from the roofing material will be difficult to transfer to the top of the solar panel. Another cause is that this test was carried out at noon (second test), meaning that a large part of the roof on this test has been covered by shadows on the solar panels starting from the morning of the first test, so because the roof is a bad conductor, then roof material heat in the part that is not covered by solar panels will not move to the part that is covered by solar panels. As for the test which was carried out at 14.30 WITA, the T3 temperature in the test using clay tile material was smaller because this test was carried out in the late afternoon so that sunlight appeared on the gap between the solar panels and the roof at a distance of 35 cm. However, from the tests carried out, it can be seen that the clay tile roof is the material that has the highest temperature, which is 38.50ºC in the test which was carried out at 12.30 WITA. To see a comparison of the two types of material, the test results are also shown in table 1 below.

III.4. Solar Panel Efficiency Comparison

For efficiency analysis, calculations are carried out by taking the sample data in Table 1 (on clay tile with a distance of 35 cm at 09.30 WITA). The parameters are as follows:

- The intensity of solar radiation, G_{bt}= 794,8 W/m^2
- Voltage, V = 19,24 V
- Current, I = 0,72 A
- Cross-sectional area, A = 0,538x0,636 = 0,342 m^2
- Temperature on top of the solar panels, T_1 = 57,59 ℃
- Temperature under solar panels, T_2 = 43,68 ℃
- Temperature between solar panels and roof, T_3 = 33,77 ℃
- Temperature on the roof, T_4 = 40,72 ℃
- Temperature under the roof, T_5 = 38,55 ℃
- Time = 9.30 WITA
- The thickness of clay tiles = 0,013 m

Input Power Calculation, $P_{in}\ (W)$

$$P_{in} = G_{bt}\ x\ A$$
$$= 794{,}8\ \mathrm{W/m^2}\ x\ 0{,}342\ \mathrm{m^2}$$

$= 271,82$ Watt

Output Power Calculation, $P_{out}\ (W)$

$$P_{out} = V\ x\ I$$
$$= 19{,}24\ \text{V x}\ 0{,}72\ \text{A}$$
$$= 13{,}85\ \text{Watt}$$

Solar Panel Efficiency Calculations, η (%)

$$\eta = \frac{P_{out}}{P_{in}}\ x\ 100\%$$
$$= \frac{13{,}85\ \text{Watt}}{271{,}82\ \text{Watt}}\ x\ 100\%$$
$$= 5{,}09\ \%$$

The following is the complete calculation of input power, output power, and solar panel efficiency shown in table 3 for clay tile material types and table 4 for ceramic tile materials.

TABLE 3. Power And Efficiency Of Solar Panel On Clay Tiles

DIstance (cm)	Time (WITA)	G_{bt} (W/m²)	V (V)	I (A)	P_{out} (W)	P_{in} (W)	η (%)
35	09.30	794.8	19.24	0.72	11.46	321.88	3.56
	12.30	1019	20.05	0.56	9.05	348.79	2.59
	14.30	695.8	30.32	28.07	9.47	238.06	3.97
30	09.30	839.7	19.65	0.61	9.33	340.06	2.74
	12.30	1006	19.58	0.64	9.93	344.20	2.89
	14.30	694.8	19.18	0.61	9.56	237.73	4.02
25	09.30	761.4	19.39	0.65	10.43	308.35	3.27
	12.30	996	19.51	0.66	10.68	340.68	3.14
	14.30	683.2	18.93	0.59	8.77	233.79	3.75
20	09.30	855	19.27	0.67	10.77	346.27	3.08
	12.30	991.9	17.96	0.65	8.37	339.38	2.46
	14.30	678.8	17.58	0.71	9.31	232.25	4.01

TABLE 3. Power And Efficiency Of Solar Panel On Clay Tiles

Distance (cm)	Time (WITA)	G_{bt} (W/m²)	V (V)	I (A)	P_{out} (W)	P_{in} (W)	η (%)
35	09.30	772	19.57	0.62	9.79	264.16	3.71
	12.30	1014	20.64	0.51	10.84	342.00	3.16
	14.30	649	19.99	0.49	8.49	187.89	4.52
30	09.30	780.3	18.97	0.72	8.46	222.13	4.49
	12.30	996.6	20.45	0.56	9.81	343.16	2.86
	14.30	800.7	20.20	0.69	9.02	184.61	4.88
25	09.30	784	19.47	0.66	10.83	268.33	4.03
	12.30	940	20.76	0.48	10.94	349.21	3.13
	14.30	801	20.90	0.47	8.99	157.54	5.69
20	09.30	799.4	19.53	0.67	10.93	273.52	4.00
	12.30	1032	18.82	0.79	11.53	348.38	3.31
	14.30	737.1	20.51	0.51	8.61	153.99	5.59

Tables 3 and 4 show the calculation results of the input power, output power, and efficiency of the solar panels on clay and ceramic tiles. To see a visual comparison, the results of the efficiency calculation are displayed in graphical form as in Figure 12. Figure 12 shows the comparison of the efficiency for several height variations of the clay and ceramic tile materials.

The highest efficiency values obtained for a height of 25 cm and 20 cm were for ceramic tile material with testing times at 14.30 WITA and 12.30 WITA, respectively 5.69% and 5.59%. While the lowest efficiency value was obtained in the clay tile test with the testing time at 12.30 WITA, namely 2.46%. The efficiency value in this experiment is influenced by the measured value of solar radiation and temperature based on the variation in height between the roof and the solar panels. Other factors that affect the efficiency of solar panels in this study, such as wind speed and sun light reflectance from the roof material to the solar panels, are assumed to have little effect in this experiment because the test framework (solar panels and roof) is not placed on tall buildings so that the factor -these factors are ignored. The weather conditions are based on a source from the Indonesian Agency for Meteorological, Climatological and Geophysics on the data collection process for clay tile, namely Wednesday, July 10, 2019, in the morning, cloudy conditions, sunny days, cloudy nights, temperatures between 23 - 32 C and humidity of 60-85%. The weather conditions during the data collection process for ceramic tile were Thursday, July 11, 2019 during cloudy days, cloudy sunny nights, temperatures between 23 - 32 ˚C and humidity of 60-85%. Table 2 and Figure 12 below show the efficiency of each test on clay and ceramic tile materials at various height distances.

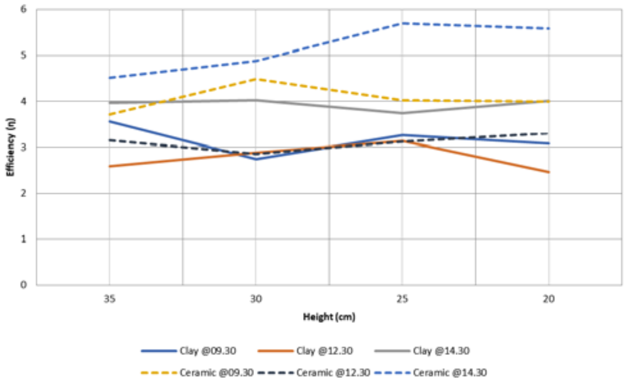

Fig 12. Comparison of the Efficiency of Solar Panels for Clay Tile Material Types

4. Conclusion

Based on the research that has been done, it can be concluded that:

1. Based on this research, the temperature characteristics between the solar panel and the roof (T3) of various types of material have an influence on the efficiency value of the solar panel, where the maximum efficiency value of the solar panel is obtained for the type of material:
   a. Clay tile at temperature (T3) 33.77°C with a maximum efficiency value of 4.22% with sunny weather conditions.
   b. Ceramic tile at temperature (T3) 33.51 C, with a maximum efficiency value of 5.69% in cloudy weather conditions.
2. Based on the results of data observations in this study, the optimal distance between solar panels and various types of roofing materials is obtained for maximum efficiency values, namely: clay tile roofs with a distance of 30 cm and ceramic tile roofs with a distance of 25 cm.

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