CHARACTERISTIC ANALYSIS OF SOLAR PANELS ON CLAY AND CERAMIC ROOF TILES

by Firman Firman

Submission date: 05-Jul-2022 11:52PM (UTC-0400)
Submission ID: 1867157367
File name: Id_25335_Said_English_Editing_OK.docx (649.86K)
Word count: 5729
Character count: 27909

CHARACTERISTIC ANALYSIS OF SOLAR PANELS ON CLAY AND CERAMIC ROOF TILES

Firman Firman[1], Nur Hamzah Said[2*], Muhammad Ruswandi Djalal[3]
(*) Corresponding author

Abstract – *In general, the Rooftop PV Panel 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, 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 of various types of material have an influence on the efficiency value of the solar panel, where the maximum efficiency value obtained for clay tile material is 4.22% and ceramic tile is 5.69%.*

Keywords: Rooftop PV Panel, Clay Tiles, Ceramic Tiles, Efficiency.

Nomenclature

G_{bt}	Radiation hitting solar panels.
θ	The angle between the rays coming to the normal plane of the panel.
P_{in}	Input power due to solar irradiance
A	Solar panel surface area
P_{out}	The power generated by solar panels
V_{oc}	Open circuit voltage on solar panels
I_{sc}	Short circuit current on solar panels
η	Solar cell efficiency
P	The output power generated by solar cells

I. 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. Due to the natural condition in Indonesia, which is relatively difficult to reach by a centralized power grid, solar energy is a must [1].

One of the photovoltaic solar energy technologies that are currently being developed is the Solar Power technology on the roof of the building or Rooftop PV Panel. It is a reliable solution for energy supply [2]. Some of the advantages of the rooftop PV panel 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].

The potential for solar energy in Indonesia is enormous [4]. Several studies on the use of rooftop PV panel include [5] discussing the possibility for implementing rooftop solar power plants in campus buildings. [6] has researched the design of rooftop off-grid solar panels in residential homes as an alternative source of electrical energy. [7] has investigated strategies for the application of solar cells (photovoltaic cells) to residential and commercial buildings. [8] has discussed the application of rooftop solar power plants to reduce electricity consumption during peak load conditions. The implementation of rooftop PV panel in buildings has been presented by many researcher [9-11]. The review papers of solar tracking system [12], cleaning mechanism of solar PV [13] and solar photovoltaic systems cooling [14] have been documented. Application of control technology and optimization in PV systems has also been developed by many researchers such as PSO-PR Power flow Control [15], control of SmartInverters grid-connected [16] and control of Grid-Connected PV Inverter using Discrete-Time Integral Variable Structure [17].

In general, the installation of rooftop PV panel only considers the power capacity to be installed [18], 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 include [19], [20], and [21], which have investigated 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 1.91°C to 2.31°C lower than the one of asbestos and zinc roofs. Tile roofs can withstand better solar radiation. The average value of the surface temperature of the tile roof has been 0.28 °C

Manuscript received January 2007, revised January 2007

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 38.71°C. Research conducted by [20] has discussed the manufacture and testing of tools in order to determine the conductivity of zinc plate, multi roof, and asbestos. The results have showed that the highest conductivity value has been found on the zinc plate (0.482 W/m°C), and the lowest conductivity value has on multi roof (0.132 W/m°C). [21] has researched the Effects of Solar Photovoltaic Panels on Roof Heat Transfer with roof temperatures below PV 2.5 times more relaxed than roofs exposed to sunlight.

Several related studies such as [22] have discussed the thermal characteristics of rooftop PV panel installations. Several previous studies have discussed the effect of the type of roof material used as a place for installing rooftop PV panel 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. This experimental work has been done in order to obtain the characteristics I-V curves and efficiency of solar panels installed on the roofs that made of clay and ceramic tile materials. The height of the solar panels on the roof has been varied at 20, 25, 30 and 35 cm.

II. Experimental method

II.1. System equipment

System equipment is illustrated in Figure 1 and Figure 2. It consists of solar panel frame and roof and research instrument placement. 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.

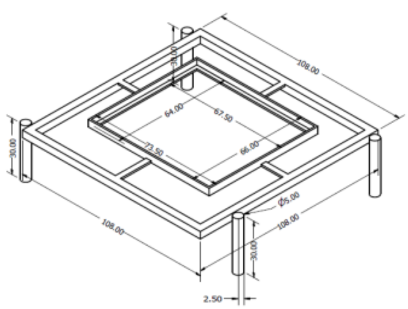

Figure 1. Dimensions of Solar Panel and Roof Frame

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.

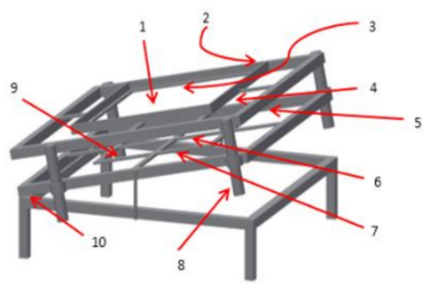

Figure 2. Research instrument placement design.

Information:

1. Solar Panel Mount
2. Temperature over solar panel, T_1 (°C)
3. Temperature under solar panel,, T_2 (°C)
4. Temperature between solar panel and roof, T_3 (°C)
5. Temperature on the roof, T_4 (°C)
6. Temperature under the roof, T_5 (°C)
7. Distance Variation Controller (cm)

II.1. Testing Procedure

After the process of manufacturing and installing the research components is completed, the arrangement of the main equipment and instruments is shown in Figure 3. The steps in the testing procedure are as follows:

1. The test has been carried out at 09.00 until 15.00 local time (WITA).
2. The angle of the solar panels is adjusted based on the type of roof used.
3. Solar panels are installed on the clay tile roof material with a distance of H1.
4. The distance (cm) between solar panels and the roof used is measured.
5. The temperature on top of the solar panel (°C) and the temperature between the solar panel and the roof (°C) are measured using the TC-O8 Thermocouple Data Logger.
6. The solar radiation (W/m^2) on a solar panel is measured using a Solar Power Meter SPM-1116SD measuring instrument.
7. The solar panel output is connected to the load panel and the toggle switch is tuned ON.
8. A Datalogger Voltmeter and an Ammeter are connected with a laptop to observe the amount of current and voltage on the solar panel.
   - In order 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

Manuscript received January 2007, revised January 2007

current and voltage and the intensity of the sun received by the solar panel. After all, measuring instruments are functioning correctly, and then data retrieval can be carried out.

9. Procedures 1 to 9 are repeated with H2 and H3 intervals.
10. Procedures 1 to 10 are repeated for ceramic tiles.

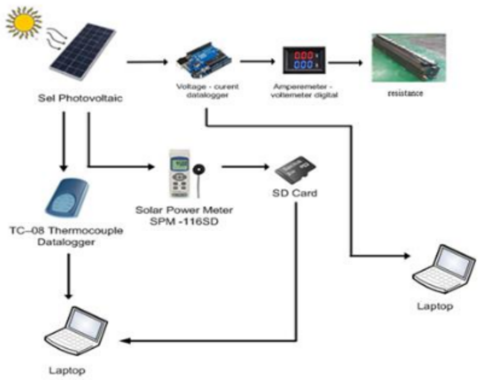

Figure 3. Schematic of rooftop PV panel

III. 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 type 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 has been conducted at 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)
- Local Time, Central Indonesian Time (zone). (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 is, the smaller the current is. 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.

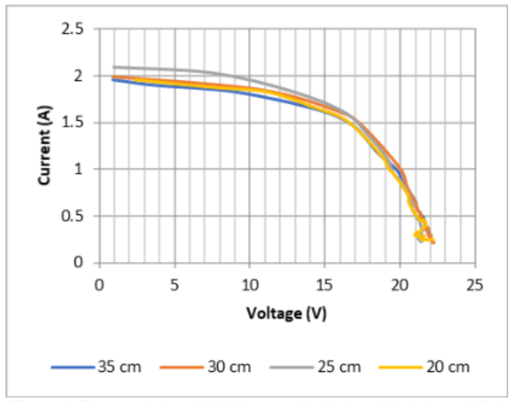

Figure 4. Characteristics of I-V Curves with Various Variations of Solar Panel Spacing on Clay Tiles for the First Experiment

Based on Figure 4, 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.

Manuscript received January 2007, revised January 2007

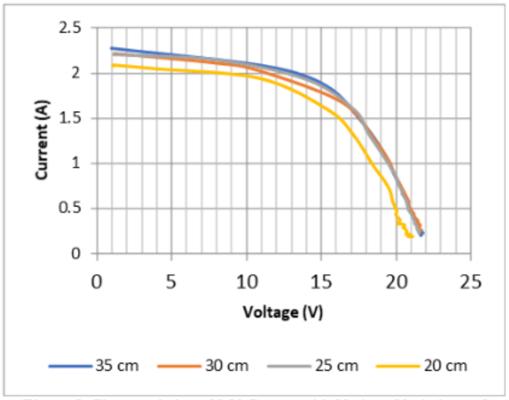

Figure 5. Characteristics of I-V Curves with Various Variations of Solar Panel Spacing on Clay Tiles for the Second Experiment

Figure 5 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 is, the smaller the current is. 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 the 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.

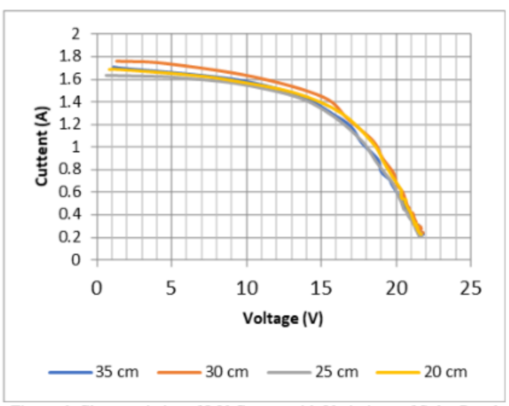

Figure 6. Characteristics of I-V Curves with Variations of Solar Panel Spacing on Clay Tiles for the Third Experiment

Figure 6 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 is, the smaller the current is. 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 7 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 is, the smaller the current is. 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 the 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.

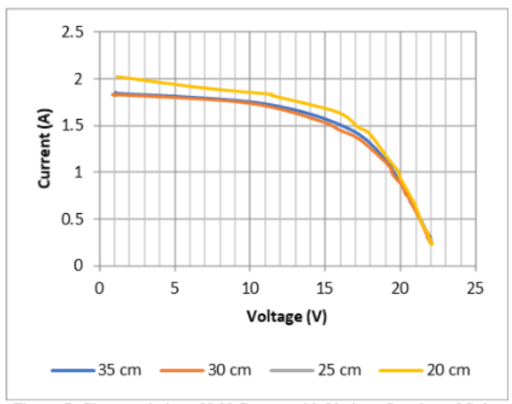

Figure 7. Characteristics of I-V Curves with Various Spacing of Solar Panels on Ceramic Tiles for the First Experiment

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

Manuscript received January 2007, revised January 2007

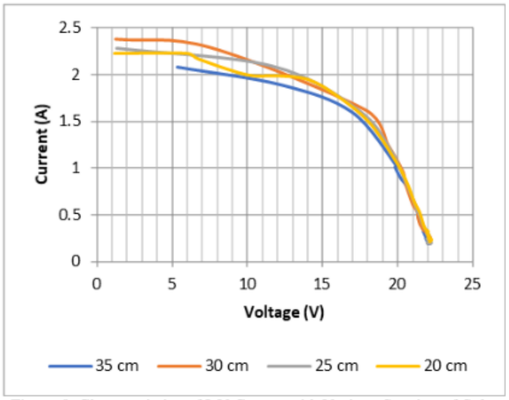

Figure 8. Characteristics of I-V Curves with Various Spacing of Solar Panels on Ceramic Tiles for the Second Experiment

Figure 8 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. The graph 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 is, the smaller the current is. 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 in Figure 8, the battery charging work area is shown as output on solar panels controlled by the Battery Control Regulator.

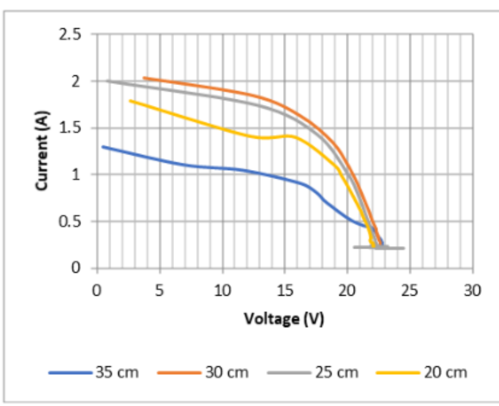

Figure 9 Characteristics of I-V Curves with Various Spacing of Solar Panels on Ceramic Tiles for the Third Experiment

Figure 9 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. The graph 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 is, the smaller the current is. 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 is controlled by the Battery Control Regulator.

III.3. Solar Panel Temperature Characteristics

Figure 10 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 has showed that at a distance of 35 cm, the highest T3 temperature in the test using clay tile roofing material has been obtained in the test carried out at 09.30 WITA, which has been 33.7°C. Next, in the test with a distance of 30 cm, the highest T3 temperature has been obtained in the test carried out at 09.30 WITA, which has been 35.9°C. Next, in the test with a distance of 25 cm, the highest T3 temperature has been obtained in the test conducted at 09.30 WITA, which has been 36°C. Next, in the test with a distance of 20 cm, the highest T3 temperature has been obtained in the test carried out at 12.30 WITA, which has been 38.5°C. This result has been slightly different from the test result at 09.30, which has been 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/m²)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)
	09.30	794.8	57.59	43.68	33.77	40.72	38.55
35	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
	09.30	839.7	58.13	45.30	35.90	40.99	40.02
30	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
	09.30	761.4	55.85	36.68	36.00	40.72	39.63
25	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
	09.30	855	57.05	37.00	38.32	40.90	40.08
20	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

The next temperature characteristic test is for ceramic tile material, with several variations of the distance. The test using the type of ceramic tile material

Manuscript received January 2007, revised January 2007

shows that at a distance of 35 cm, the highest T3 temperature in the test using clay tile roofing material has been obtained in the test carried out at 14.30 WITA, which has been 34.55ºC. Next, in the test with a distance of 30 cm, the highest T3 temperature has been obtained in the test carried out at 14.30 WITA, which has been 33.64ºC. Next, in the test with a distance of 25 cm, the highest T3 temperature has been obtained in the test has been carried out at 12.30 WITA, namely 34.03ºC. Next, in the test with a distance of 20 cm, the highest T3 temperature has been obtained in the test carried out at 14.30 WITA, which has been 35.88ºC. Table 2 shows the results of testing the characteristics of solar panels on ceramic tiles.

TABLE II.
COMPARISON OF TEMPERATURE CHARACTERISTICS OF CERAMIC TILES

Distance (cm)	Time (WITA)	G_{bt} (W/m²)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)
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

Testing the temperature characteristics of the solar panels on clay tiles has 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 has 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 has been 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. Therefore, since 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 covered by solar panels. As for the test carried out at 14.30 WITA, the T3 temperature in the test using clay tile material has been smaller because this test has been 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 38.50 °C in the test carried out at 12.30 WITA.

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/m²
- Voltage, V = 19.24 V
- Current, I = 0.72 A
- Cross-sectional area, A = 0.538x0.636 = 0.342 m²
- Temperature on top of the solar panels, T_1 = 57.59 °C
- Temperature under solar panels, T_2 = 43.68 °C
- Temperature between solar panels and roof, T_3 = 33.77 °C
- Temperature on the roof, T_4 = 40.72 °C
- Temperature under the roof, T_5 = 38.55 °C
- Time = 9.30 WITA
- The thickness of clay tiles = 0.013 m

Input Power , P_{in} (W)

$$P_{in} = G_{bt}\ x\ A = 794.8\ \mathrm{W/m^2}\ x\ 0.342\ \mathrm{m^2} = 271.82\ \mathrm{Watt}$$

Output Power , P_{out} (W)

$$P_{out} = V\ x\ I = 19.24\ \mathrm{V} \times 0.72\ \mathrm{A} = 13.85\ \mathrm{Watt}$$

Solar Panel Efficiency , η (%)

$$\eta = \frac{P_{out}}{P_{in}}\ x\ 100\% = \frac{13.85\ \mathrm{Watt}}{271.82\ \mathrm{Watt}}\ x\ 100\% = 5.09\ \%$$

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.

Input Power, P_{in} (W)

$$P_{in} = G_{bt}\ x\ A = 794.8\ \mathrm{W/m^2}\ x\ 0.342\ \mathrm{m^2} = 271.82\ \mathrm{Watt}$$

Output Power, P_{out} (W)

$$P_{out} = V\ x\ I = 19.24\ \mathrm{V} \times 0.72\ \mathrm{A} = 13.85\ \mathrm{Watt}$$

Solar Panel Efficiency, η (%)

$$\eta = \frac{P_{out}}{P_{in}}\ x\ 100\% = \frac{13.85\ \mathrm{Watt}}{271.82\ \mathrm{Watt}}\ x\ 100\% = 5.09\ \%$$

Manuscript received January 2007, revised January 2007

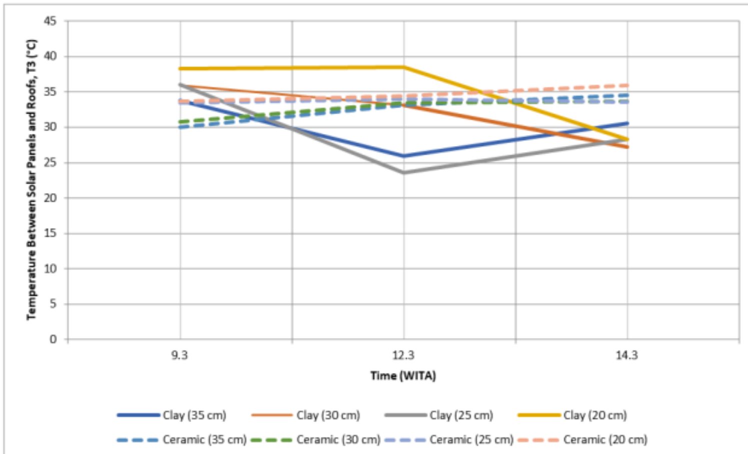

Figure 10. Comparison of temperature characteristics for clay and ceramic tile types

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 (%)
	09.30	794.8	19.24	0.72	11.46	321.88	3.56
35	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
	09.30	839.7	19.65	0.61	9.33	340.06	2.74
30	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
	09.30	761.4	19.39	0.65	10.43	308.35	3.27
25	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
	09.30	855	19.27	0.67	10.77	346.27	3.08
20	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 4.
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 (%)
	09.30	772	19.57	0.62	9.79	264.16	3.71
35	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
	09.30	780.3	18.97	0.72	8.46	222.13	4.49
30	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
	09.30	784	19.47	0.66	10.83	268.33	4.03
25	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
	09.30	799.4	19.53	0.67	10.93	273.52	4.00
20	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. A visual comparison of the efficiency calculation is displayed in graphical form in Figure 11 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 have been for ceramic tile material with testing times at 14.30 WITA and 12.30 WITA, respectively 5.69% and 5.59%. The lowest efficiency value has been 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 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 have been Thursday, July 11, 2019 during cloudy days, cloudy sunny nights, temperatures between 23 - 32 ˚C and humidity of 60-85%.

Manuscript received January 2007, revised January 2007

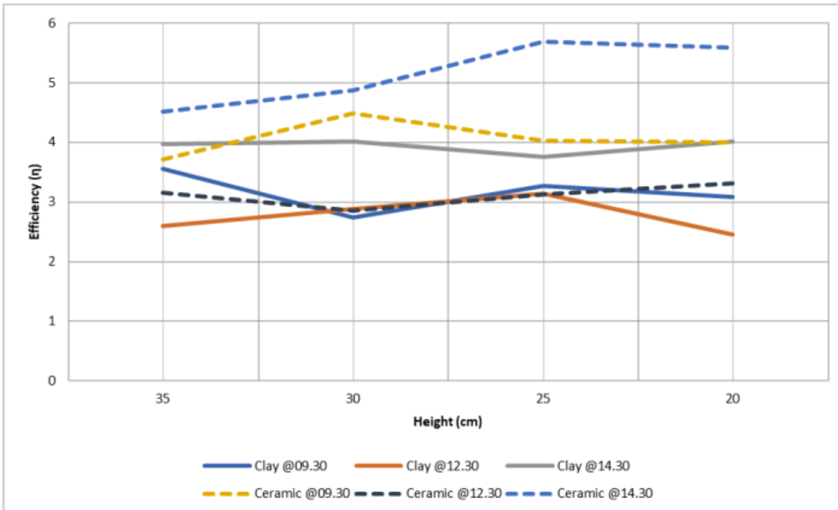

Figure 11. Comparison of the Efficiency of Solar Panels for Clay Tile Material Types

IV. Conclusion

I-V curve characteristics and efficiency of roof-mounted solar panels made of clay and ceramic materials have been successfully carried out. The experiment has been performed at the height of the solar panel on the roof 20, 25, 30 and 35 cm. The temperature characteristics between the solar panel and the roof (T3) of various types 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. The Clay tile at temperature (T3) 33.77°C with a maximum efficiency value of 4.22% with sunny weather conditions, while Ceramic tile at temperature (T3) 33.51 C, with a maximum efficiency value of 5.69% in cloudy weather conditions.

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.

REFERENCES

[1] D. Septiadi, P. Nanlohy, M. Souissa, and F. Y. Rumlawang, Proyeksi potensi energi surya sebagai energi terbarukan (Studi wilayah Ambon dan sekitarnya), Jurnal Meteorologi dan Geofisika, vol. 10, no. 1, 2009.

[2] J. Peng and L. Lu, Investigation on the development potential of rooftop PV system in Hong Kong and its environmental benefits, Renewable and Sustainable Energy Reviews, vol. 27, pp. 149-162, 2013.

[3] S. Castellanos, D. A. Sunter, and D. M. Kammen, Rooftop solar photovoltaic potential in cities: how scalable are assessment approaches?, Environmental Research Letters, vol. 12, no. 12, p. 125005, 2017.

[4] N. Handayani, Potency of solar energy applications in Indonesia, International Journal of Renewable Energy Development, vol. 1, no. 2, pp. 33-38, 2012.

[5] E. Tarigan, Simulation and feasibility studies of rooftop PV system for university campus buildings in Surabaya, Indonesia, International Journal of Renewable Energy Research, vol. 8, no. 2, pp. 895-908, 2018.

[6] M. F. Hakim, Perancangan Rooftop Off Grid Solar Panel pada rumah tinggal sebagai alternatif sumber energi listrik, Dinamika DotCom, 2017.

[7] D. S. Mintorogo, Strategi aplikasi sel surya (photovoltaic cells) pada Perumahan dan bangunan komersial, DIMENSI (Journal of Architecture and Built Environment), vol. 28, no. 2, 2000.

[8] S. Syafii, N. Novizon, W. Wati, and D. Juliandri, Feasibility Study of Rooftop Grid Connected PV System for Peak Load Reduction, Proceeding of the Electrical Engineering Computer Science and Informatics, vol. 5, no. 5, pp. 231-235, 2018.

[9] Y. Kotak, E. Gago, P. Mohanty, and T. Muneer, Installation of roof-top solar PV modules and their impact on building cooling load, Building Services Engineering Research & Technology, vol. 35, no. 6, 2014.

[10] H. Altan, Z. Alshikh, V. Belpoliti, Y. K. Kim, Z. Said, and M. Al-chaderchi, An experimental study of the impact of cool roof on solar PV electricity generations on building rooftops in Sharjah, UAE, International Journal of Low-Carbon Technologies, vol. 14, no. 2, pp. 267-276, 2019.

[11] F. Salamanca, M. Georgescu, A. Mahalov, M. Moustaoui, and A. Martilli, Citywide impacts of cool roof and rooftop solar photovoltaic deployment on near-surface air temperature and cooling energy demand, Boundary-Layer Meteorology, vol. 161, no. 1, pp. 203-221, 2016.

[12] S. V. J. Prakash and P. K. Dhal, A Review: Solar Tracking System with Grid Used in Kurnool Ultra Mega Solar Park, 2019, Solar PV system; Solar Radiation; Grid-Tied Solar System; Two Axis Tracking System; Vertical Axis Tracking System; Horizontal Axis Tracking System; Estimated Losses vol. 14, no. 3, 2019.

[13] P. A. Patil, J. Bagi, and M. Wagh, A review on cleaning mechanism of solar photovoltaic panel. 2017, pp. 250-256.

[14] J. Siecker, K. Kusakana, and B. P. Numbi, A review of solar photovoltaic systems cooling technologies, Renewable and Sustainable Energy Reviews, vol. 79, pp. 192-203, 11/01 2017.

[15] D. Adolfo, D. P. Andrea, D. N. L. Pio, and M. Santolo, PSO-PR power flow control of a single-stage grid-connected PV inverter, in 2017 IEEE 6th International Conference on Renewable Energy Research and Applications (ICRERA), 2017, pp. 788-792.

[16] A. D. Pizzo, L. P. D. Noia, and S. Meo, Super twisting sliding mode control of smart-inverters grid-connected for PV applications, in 2017 IEEE 6th International Conference on

Manuscript received January 2007, revised January 2007

Renewable Energy Research and Applications (ICRERA), 2017, pp. 793-796.
[17]S. Meo and V. Sorrentino, Discrete-time integral variable structure control of grid-connected PV inverter, *Journal of Electrical Systems,* vol. 11, pp. 102-116, 01/01 2015.
[18]A. S. Alghamdi, Potential for Rooftop-Mounted PV Power Generation to Meet Domestic Electrical Demand in Saudi Arabia: Case Study of a Villa in Jeddah, *Energies,* vol. 12, no. 23, p. 4411, 2019.
[19]A. Rahmat, E. Prianto, and S. B. Sasongko, Studi Pengaruh Bahan Penutup Atap terhadap Kondisi Termal pada Ruang Atap, *Jurnal Arsitektur ARCADE,* vol. 1, no. 1, pp. 35-40, 2017.
[20]E. Selparia, M. Ginting, and R. Syech, "Pembuatan dan pengujian alat untuk menentukan konduktivitas plat seng, multiroof dan asbes," Riau University.
[21]A. Dominguez, J. Kleissl, and J. C. Luvall, Effects of solar photovoltaic panels on roof heat transfer, *Solar Energy,* vol. 85, no. 9, pp. 2244-2255, 2011.
[22]S. Odeh, Thermal performance of dwellings with rooftop PV panels and PV/thermal collectors, *Energies,* vol. 11, no. 7, p. 1879, 2018.

Authors' information

[1,2,3]Department of Mechanical Engineering, Energy Power Plant Engineering, State Polytechnic of Ujung Pandang.
Email : [1]firman@poliupg.ac.id, [2]hamzah_said@poliupg.ac.id
[3]wandi@poliupg.ac.id

Firman Firman was born in Wajo, on March 11, 1964. He obtained his bachelor degree from Hasanuddin University, Makassar (Indonesia) in 1989 majoring Mechanical Engineering. Then, he finished his master degree from Hasanuddin University, (Makassar, Indonesia) in 2003 in the field of Mechanical Engineering. His research is mainly in Cooling Engineering, Fluid Mechanics, Thermodynamics Engineering, and Energy Management. He is currently a lecturer in the Department of Energy Power Plant and the Head of Energy Conversion Laboratory, State Polytechnic of Ujung Pandang.

Nur Hamzah was born in Makassar, on November 11, 1963. He obtained his bachelor degree from Hasanuddin University, Makassar (Indonesia) in 1988 majoring Mechanical Engineering. Then, he finished his master degree from Sepuluh Nopember Institute of Technology, (Surabaya, Indonesia) in 2000 in the field of Mechanical Engineering. Then, he finished his doctoral degree from Universiti Teknologi Malaysia (UTM) in 2018 in the field of Thermo Fluid. His research is mainly in Thermo Fluid, Renewable Energy, and Energy Management. He is currently a lecturer in the Department of Energy Power Plant, State Polytechnic of Ujung Pandang.

Muhammad Ruswandi Djalal was born in Ujung Pandang, on march 11, 1990. He obtained his bachelor degree from State Polytechnic of Ujung Pandang (Makassar, Indonesia) in 2012 majoring Energy Engineering. Then, he finished his master degree from Sepuluh Nopember Institute of Technology, (Surabaya, Indonesia) in 2015 in the field of Electrical Engineering. His research is mainly in Power System Stability, Renewable Energy, and Artificial Intelligent. He is currently a lecturer in the Department of Energy Conversion, State Polytechnic of Ujung Pandang.

Manuscript received January 2007, revised January 2007

CHARACTERISTIC ANALYSIS OF SOLAR PANELS ON CLAY AND CERAMIC ROOF TILES

ORIGINALITY REPORT

9%	9%	7%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Muhammad Yusuf Yunus, Muhammad Ruswandi Djalal, Marhatang Marhatang. "Optimal Design Power System Stabilizer Using Firefly Algorithm in Interconnected 150 kV Sulselrabar System, Indonesia", International Review of Electrical Engineering (IREE), 2017 Publication	3%
2	Submitted to Manipal University Student Paper	2%
3	Submitted to Gulf University for Science & Technology Student Paper	2%
4	jurnal.universitaskebangsaan.ac.id Internet Source	1%
5	beei.org Internet Source	<1%
6	www.neliti.com Internet Source	<1%

7	Cedric Taruna, Levin Halim, Bagus Made Arthaya. "Initial Concept for Increasing Polycrystalline Fixed Solar Panel Efficiency with Water Treatments", 2019 International Conference on Mechatronics, Robotics and Systems Engineering (MoRSE), 2019 Publication	<1%
8	hal.archives-ouvertes.fr Internet Source	<1%
9	Bambang Winardi, Enda Wista Sinuraya, Agung Nugroho, Denis. "Design and Implementation of Rooftop off Grid Solar Panel for Household Electricity Loads", 2021 8th International Conference on Information Technology, Computer and Electrical Engineering (ICITACEE), 2021 Publication	<1%
10	www.jmest.org Internet Source	<1%

Exclude quotes Off

Exclude bibliography On

Exclude matches < 15 words