

Characteristic Analysis of Solar Panels on Clay and Ceramic Roof Tiles

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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 characteristics between 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%. **Copyright © 2022 Praise Worthy Prize S.r.l. - All rights reserved.**

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

Nomenclature

G_{bt}	Radiation hitting solar panels
θ	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
Pout	The power generated by solar panels
V_{oc}	Open circuit voltage on solar panels
Isc	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 gridconnected [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 [23]-[25]. 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 [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 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 been 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 4×4 cm is used and also angled iron measuring 3×3 cm. Acrylic material is used for the material on the load panel. In designing the load panel as the output of the solar panel, the acrylic material is used with a size of 75×60 cm.



Fig. 1. Dimensions of Solar Panel and Roof Frame



2.

- Temperature over solar panel, T1 (°C) 3. Temperature under solar panel, T₂ (°C)
- Temperature between solar panel and roof, T₃ (°C) 4.
- 5. Temperature on the roof, T₄ (°C)
- Temperature under the roof, T₅ (°C) 6.
- 7 Distance Variation Controller (cm)

Fig. 2. Research instrument placement design

II.2. 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 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.

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

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/m²);
- Temperature over solar panels, T_1 (°C);
- Temperature under solar panel, T₂ (°C);
- Temperature between solar panel and roof, T_3 (°C);
- Temperature on the roof, T_4 (°C);
- Temperature under the roof, T_5 (°C);
- 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.



Fig. 3. Schematic of rooftop PV panel





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

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 4, the battery charging work area is shown as an output on a solar panel controlled by a BCR (Battery 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. 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.



Fig. 5. Characteristics of I-V Curves with Various Variations of Solar Panel Spacing 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 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.



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





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

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.

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



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

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 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 I shows the results of testing the characteristics of solar panels on clay tiles.



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

TABLE I

COMPARISON OF TEMPERATURE CHARACTERISTICS OF CLAY TILES							
Distance	Time	G_{bt}	T_1	T_2	T_3	T_4	T_5
(cm)	(WITA)	(W/m^2)	(°C)	(°C)	(°C)	(°C)	(°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 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 34.55 °C.

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 33.64 °C. 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 34.03 °C. 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 35.88 °C.

Table II shows the results of testing the characteristics of solar panels on ceramic tiles. 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.

			Т	ABLEI	Ι			
	COMPARISON OF TEMPERATURE CHARACTERISTICS OF CERAMIC TILES							
	Distance	Time	G_{bt}	T_1	T_2	T_3	T_4	T_5
	(cm)	(WITA)	(W/m^2)	(°C)	(°C)	(°C)	(°C)	(°C)
		09.30	772	43.92	40.52	30.01	33.68	30.81
	35	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
		09.30	780.3	44.12	40.48	30.74	36.22	34.88
	30	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
		09.30	784	46.24	41.87	33.46	35.90	34.23
	25	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
		09.30	799.4	46.75	44.59	33.62	37.00	35.13
	20	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

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 I (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, $A = 0.538 \times 0.636 = 0.342 \text{ m}^2$;
- Temperature on top of the solar panels, $T_1 = 57.59 \text{ }^{\circ}\text{C}$;
- Temperature under solar panels, $T_2 = 43.68 \text{ °C}$;
- Temperature between solar panels and roof, $T_3 = 33.77 \text{ }^{\circ}\text{C}$;
- Temperature on the roof, $T_4 = 40.72 \text{ °C}$;
- Temperature under the roof, $T_5 = 38.55 \text{ °C}$;
- Time = 9.30 WITA;
- The thickness of clay tiles = 0.013 m; Input Power, P_{in} (W):

$$P_{in} = G_{bt} \times A = 794.8 \text{ W/m}^2 \times 0.342 \text{ m}^2 = 271.82 \text{ W}$$

Output Power, *P*_{out} (W):

$$P_{out} = V \times I = 19.24 \text{ V} \times 0.72 \text{ A} 13.85 \text{ W}$$

Solar Panel Efficiency, η (%):

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{13.85 \text{ W}}{271.82 \text{ W}} \times 100\% = 5.09 \%$$

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

Input Power, P_{in} (W):

$$P_{in} = G_{ht} \times A = 794.8 \text{ W/m}^2 \times 0.342 \text{ m}^2 = 271.82 \text{ W}$$

Output Power, *P*_{out} (W):

$$P_{out} = V \times I = 19.24 \text{ V} \times 0.72 \text{ A} 13.85 \text{ W}$$

Solar Panel Efficiency, η (%):

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{13.85 \text{ W}}{271.82 \text{ W}} \times 100\% = 5.09\%$$

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



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TABLE III POWER AND EFFICIENCY OF SOLAR PANEL ON CLAY TILES Distance VPou Time G_{bt} I P_{ii} η (WITA) (W/m^2) (V) (W) (W) (%) (cm)(A)09.30 794.8 19.24 0.72 11.46 321.88 3.56 348.79 35 12 30 1019 20.05 0.56 9.05 2 59 14.30 695.8 30.32 28.07 9.47 238.06 3.97 2.74 09.30 839.7 19.65 0.61 9.33 340.06 30 12.30 1006 19.58 9.93 344.20 2.89 0.64 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 10.68 340.68 3.14 0.66 14.30 683.2 18.93 233.79 0.59 8.77 3.75

19.27

17.96

17.58

0.67

0.65

0.71

10.77

8.37

9.31

346.27

339.38

232.25

3.08

2.46

4.01

TABLE IV POWER AND EFFICIENCY OF SOLAR PANEL ON CLAY TILES P_{in} Distance Time P_{out} G_{bt} V 1 η (WITA) (W/m^2) (V) (A) (W) (W) (%) (cm) 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

09.30

12.30

14.30

20

855

991.9

678.8

00	12.00		20.0.	0.01	10.0.	0.2.00	0.10	
	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	
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 III and IV 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%.



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

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IV. Conclusion

I-V curve characteristics and efficiency of roofmounted 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 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.

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.

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