2D Heat Distribution Mapping of Monocrystalline Type Photovoltaic Placed in Universitas Budi Luhur Jakarta

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***Abstract*— Due to exposure to direct sunlight, rooftop PV panels often suffers from heating. Performance of monocrystalline photovoltaic (MCPV) cell/panel is affected by its thermal properties, therefore, this research aims to measure the performance of MCPV through 2-dimensional heat mapping to determine the most efficient cooling scheme for the PV to maintain its most optimum performance. The measurement, mapping, and calculation is conducted on an array of experimental rooftop PV panel installed on a building, heat mapping data is taken from 55 points on PV surface. Measurement result shows that the high temperature of the MCPV panel is around 58,6°C – 64,7°C. Based on the results, the recommendation of temperature sensor placement for the cooling process is located at point 23 and 47 .**

Keywords— *Heat mapping, monocrystalline, photovoltaic, cooling, performance, optimization*.

I. INTRODUCTION

Indonesia is located on the equator, therefore almost every part of Indonesia gets abundant sunlight all year round. Thus, Indonesia has a high potential for solar power electricity as an alternative energy source. Solar power can be converted into electricity by photovoltaic (PV) cells. Photovoltaic cells maximum performance is achieved in certain temperature, which is affected by weather conditions and other environmental factors, such as dust and other obstructions. The temperature of the photovoltaic cell/panel plays an important role in the system efficiency because of the fluctuating of radiation intensity, the efficiency system will also change instantly.

As long as the PV panels receives sun light, the energy from solar radiation is converted into electrical energy and there is an increase in the temperature of solar cells [1][2]. The problem of PV panel is that the output power tends to decrease due to the environmental temperature. Another factor that influences the power produced by PV is from solar radiation [3]–[5][6] [7].

Fluctuating environmental conditions causes changes of the surface temperature of the solar cell, and there is a possibility of changes in the power generated by the solar cell caused by differences in the surface temperature of the solar cell. To overcome this temperature problem, a cooling model has to be developed. Temperature distribution has to be known first to increase the efficiency of cooling model. In [8], the three dimensional computational fluid dynamics simulation of fluid flow and heat transfer from a photoviltaic module is developed. Based on the results, temperature distribution and output power can be predicted.

In this paper, the heat distribution mapping of monocrystalline photovoltaic is conducted to determine the location of the cooling sensor that will be placed so that the cooling process runs effectively because it is right on target.

The remainder of this paper is arranged as follows. The characters of monocrystalline photovoltaic is presented in Section II. Section III describes the experiment methods. The simulation results are evaluated in Section IV. Finally, the conclusions of this research are remarked in Section V.

II. CHARACTERISTICS OF MONOCRYSTALLINE PHOTOVOLTAIC

Monocrystalline is one of the photovoltaic types which has the high efficiency up to 15%. This type is designed for high power usage with extreme weather conditions. Yet, the weakness of monocryrstalline is the efficiency will decrease significantly when the weather is cloudy.

The power capacity is notated in watt peak (Wp) which based on 1000 W/m^2 solar intensity radiation that perpendicular with the photovoltaic at 25°C temperature. Photovoltaic has the correlation with current and voltage. When in open circuit mode, the current cell will be zero and the voltage cell will be on its maximum value, known as open circuit voltage (V_{oc}).

Heat transfer occurs by conduction from high-temperature regions to low-temperature regions. The conduction heat transfer rate can be expressed by Fourier's Law [9].

$$q = -kA\left(\frac{dT}{dx}\right) \text{ watt}$$

with, q = heat transfer rate (watt), k = thermal conductivity (W/mK), A = cross-sectional area located in the heat flow (K/m); dT/dx = temperature gradient in heat flow (K/m)

III. MEASUREMENT OF TEMPERATURE FOR 2D HEAT DISTRIBUTION MAPPING

Object of study in this paper, a solar power generation system is designed using a PV panel placed on the roof top of the 5th floor of one of the buildings on the Budi Luhur University campus in Jakarta with coordinates -6.234027LU, 106.747365BT as shown in Fig. 1. The PV panel is placed in a position with a slope of 30 degrees facing the sun

The solar panel used in this study has the following specifications:

Rate Maximum Power (Pm)	:	200 watt
Open-Circuit Voltage (Voc)	:	44,9 V
Short-Circuit Current (Isc)	:	5,49 A
Voltage at Pmax (Vmp)	:	36,6 V
Current at Pmax (Imp)	:	5,19 A
maximum system Voltage	:	1000 VDC
Dimensi	:	1580 x 808 x 35 mm
Normal Operating Cell Temp	:	47^{0}C ± 2^{0}C

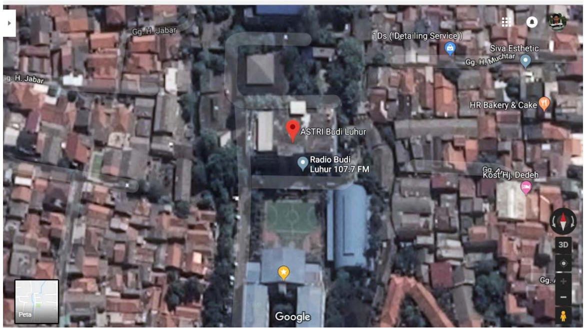

Fig. 1. Location of photovoltaic coordinates

PV panel temperature measurements are carried out directly using an infrared thermometer at 55 points on the surface of the PV panel. Fig. 2 shows the solar panel temperature measurements points. Measurements are taken from 11.00 to 12.5. The timing of the measurement is based on the highest level of heating on the PV panel due to exposure to the sun's heat.

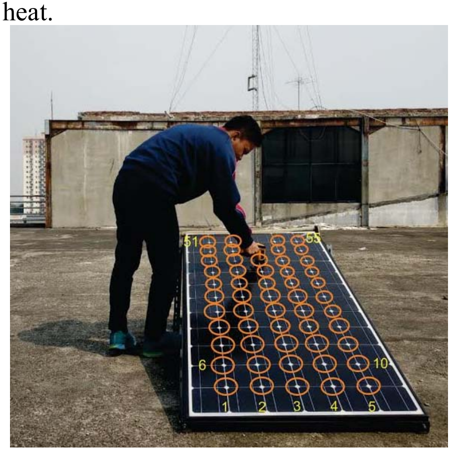

Fig. 2. Photovoltaic temperature measurement point.

The results of temperature measurements will be processed into 2D maps which represent the heat distribution that occurs on the surface of the PV panel. From the 2D map the heat distribution of the surface of the PV panel, will be known the lowest temperature point to the highest. The point in the high temperature PV panel will be a recommendation of sensor placement for automatic temperature monitoring and temperature control of PV panels.

IV. PERFORMANCE STUDY WITH 2D HEAT DISTRIBUTION MAP AND ANALYSIS

The photovoltaic that used in this experiment has a normal temperature about 47 ºC ± 2 ºC and operating temperature of about 40 ºC s/d 85 ºC. Fig. 3 - 5 shows the experiment result which results in 2D heat mapping distribution of photovoltaic. Based on the 55 points of the experiment, the lowest, highest, and average value are obtained. The lowest, highest, and average value are calculated based on all of the data during the measurement time.

From Fig. 3, it can be seen that the temperature value is around 43,1 ºC – 48,9 ºC. Moreover, these values are still in the normal cell temperature range. Based on the low-temperature mapping, no recommendation sensor placement at this area.

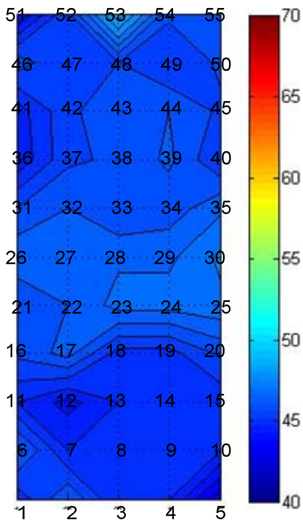

Fig. 3. The lowest temperature mapping of all measurement points

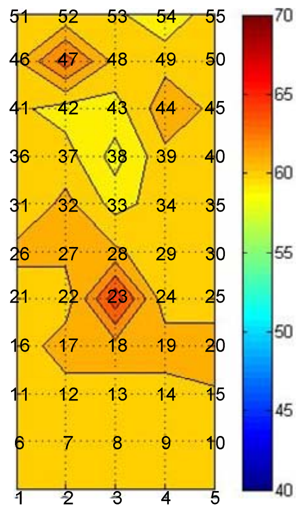

Fig. 4. Highest temperature map of all measurement points

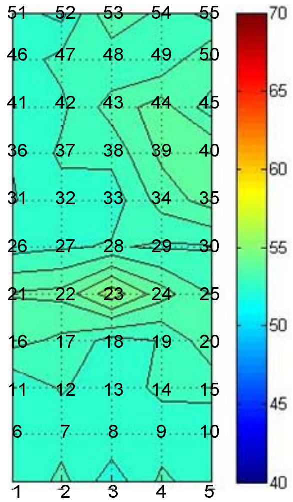

Fig. 5. Average temperature map of all measurement points

From Fig. 4, it can be seen that the value is around 58,6 °C – 64,7 °C. It is also still around the normal cell temperature range. The sensor placement recommendation based on the high-temperature mapping is located at a point: 23 and 47. The area that has to be noticed is around 3,64% of the total area. The sensor placement aims to detect the increment of photovoltaic temperature which can decrease the efficiency system [9], to cost efficiency, and to know the data sampling frequency.

Based on the measurement in Fig. 5, the average value is at 52,2°C – 55,3 °C. If those values are compared to the normal cell temperature, the average value are still above the normal value.

Based on the recommendation replacement sensor on point 23 and 47, the figure of characteristic about panel temperature, ambient temperature, solar radiation and wind speed show on Fig. 6.

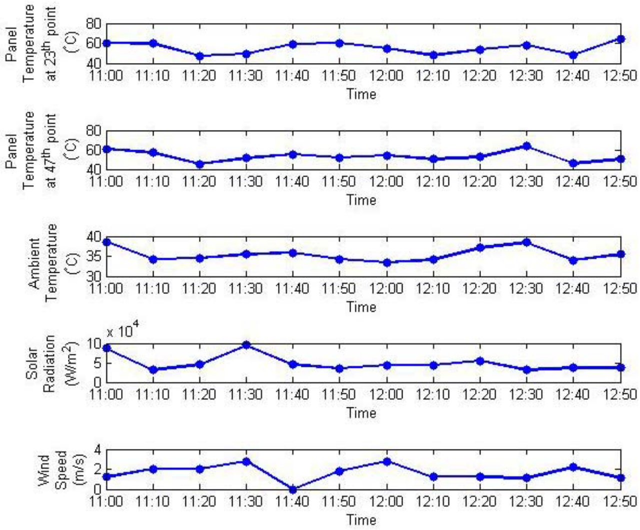

Fig. 6. Characteristic about panel temperature, ambient temperature, solar radiation and wind speed point 23 and 47.

Solar radiation fluctuations at measurements range from 31400 to 95400 W/m^2. The lowest solar radiation occurs at 12.30 and the highest at 11:30. Ambient temperature fluctuations at measurements range from 33.5 °C - 38.6 °C. The lowest ambient temperature occurs at 12.00 and the highest at 11.00.

Fluctuations Wind speed that occurs when measurements are in the range 0 - 2.8 m/s. The lowest wind speed occurs at 11:40 and the highest wind speed occurs at 11:30 and 12.00.

The panel temperature fluctuations at measurements range from 43.1 °C - 64.7 °C. The panel temperature reaches the highest temperature at 12.50 where radiation is 37200 W/ m^2, wind speed is 1.1 m/s and ambient temperature is 35.5°C.

At measurement points 23 and 47, there was a temperature panel fluctuation of 6x. The first fluctuation is the decrease in panel temperature at 11.00 to 11.20. The measurement at 11.00 recorded the temperature panel at point 23 was 60.4 °C and the temperature panel decreased to 47.2 °C. While at point 47 the measurement at 11.00 was 60.7 °C and the temperature decreased to 45.5 °C At the same time measurement, the ambient temperature also decreased from 38.6 °C to 34.5 °C. The cause is due to solar radiation decreased from 87 500 W / m^2 at 11:00 into 45000 W / m^2 at 11:20 hours. Wind speed is also the cause of the decrease in temperature panel because the measurement at 11.00 wind speed is only 1.2 m / s while at 11:20 a wind speed becomes 2 m / s.

The second fluctuation, there was an increase in the panel temperature at 11.20 to 11.40. Measurements at 11:20 recorded temperature at point 23 was 47.2 °C and the temperature had increased to 59.3 °C at 11:40. At the measurement point 47, there was a change in temperature from 45.5 °C at 11:20 to 55.4 °C at 11:40. At the same time measurement, the ambient temperature also experienced an increase in temperature from 34.5 °C to 35.9 °C. This is possible because of the increase in solar radiation from 45000 W / m^2 to 45200 W / m^2. Wind speed is also a cause because there is a decrease in wind speed from 2 m / s to 0 m / s.

The third fluctuation, there is a decrease in the temperature panel at 11.40 to 12.10. The temperature at the 23rd measurement point is 59.3 °C at 11:40 and has decreased to 48 °C. At the 47th measurement point, the temperature was recorded at 55.4 °C at 11:40 and experienced a temperature drop of up to 50.1 °C at 12:10. ambient temperature also decreased from 35.9 °C at 11:40 to 34.1 °C at 12:10. solar radiation also experienced a decline from 45200 W / m^2 at 11:40 to 44250 W / m^2 at 12:10. recorded wind speeds from 11:40 to 12.10 have increased from 0 m / s to 1.2 m / s.

The fourth fluctuation, there is an increase in temperature panel at 12.10 to 12.30. the temperature panel at the measurement point 23 is 48 °C at 12:10 and has increased to reach 58.3 °C at 12.30. at the measurement point 47, the temperature at 12:10 was 50.1 °C and reached 63.5 °C at 12:30. ambient temperature also increased from 12.10 at 34.1 °C to 38.5 °C at 12.30. solar radiation at 12.10 is 44250 W / m^2 has increased to 54200 W / m^2 at 12.20 and experienced a decline back to 31400 at 12.30. wind speed has decreased from 1.2 m / s at 12.20 to 1.1 m / s at 12.30.

The fifth fluctuation, there was a decrease in the temperature panel at 12.30 to 12.40. at 12:30 a.m., at the measurement point 23 the temperature panel was 58.3 °C and at 12.40 it fell to 48.3 °C. at point 47, the temperature panel was recorded at 63.5 ºC at 12.30 and fell to 46.1 ºC at 12.40. ambient temperature also decreased from 38.5 ºC to 34 ºC. However, solar radiation has increased from 31400 W / m^2 to 36900 W / m^2. Even though solar radiation has increased, the panel temperature has decreased relatively because the recorded wind speed has increased from 1.1 m / s to 2.2 m / s.

The sixth fluctuation, there was an increase in the temperature panel at 12.40 to 12.50. at the measurement point 23, the temperature was recorded at 48.3 ºC and increased to 64.7 ºC. at the measurement point 47, the temperature increased from 46.1 ºC to 50.3 ºC. ambient temperature also increased from 34 ºC to 35.5 ºC. solar radiation also increased from 36900 W / m^2 to 37200 W / m^2. Whereas the recorded wind speed is experiencing a decrease of 2.2 m / s to 1.1 m / s. From Fig. 6 it can be seen that the photovoltaic temperature is not affected only by solar radiation changes, but also influenced by changes in ambient temperature and wind speed.

V. Conclusion

The photovoltaic temperature can significantly affect the performance system. Thus, it has to be managed. To control the photovoltaic temperature, the monitoring system is important. It can be done by placing the temperature sensor at some points which based on the experiment. The furhter avenues of research will be adopting the sensor network of temperature in order to monitoring the real time temperature.

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