The Improvement of Solar Panel Performance Using Cooling Method

Fadliondi Fadliondi[*], Budiyanto Budiyanto and Prian Gagani Chamdareno

Department of Electrical Engineering, Universitas Muhammadiyah Jakarta, Jakarta, Indonesia

([*]**Corresponding author's e-mail: fadliondi@ftumj.ac.id**)

Abstract

The improvement of solar panel using cooling method has been investigated. By applying cooling method, the open circuit voltage and the power of the solar panel has increased significantly. By applying cooling method, the temperature of the solar panel decreased from 48.7 to 25.7 °C at irradiance of 968.3 W/m^2. The open circuit voltage also increased from around 17.91 to 21.89 V when cooling was applied. The cooling method was by submersion of solar panel. The solar panel was put inside a plastic bag and put inside a container containing water. As the result, cooling solar panels with submersion method can reduce the temperature from 48.7 to 25.7 °C resulting in a significant increase in the output power of the solar panel from 8.02 W to 10.99 W.

Keywords: Solar, Panel, Performance, Cooling, Battery

Nomenclature

a-Si	amorphous silicon
A	surface area of solar panel
CdTe	cadmium telluride
CIGS	copper indium gallium (di) selenide
FF	fill factor
I	current
I_{MP}	current at maximum power
I_{PH}	photon current
I_S	saturation current
I_{SC}	short-circuit current
k	Boltzmann constant
n	diode ideality factor
P_{IN}	power per unit area
q	elementary charge
R_S	series resistance
R_{SH}	shunt resistance
T	absolute temperature
V	voltage across the output terminals
V_{OC}	open-circuit voltage
V_{MP}	voltage at maximum power point
η	efficiency

Introduction

The renewable energy is an alternative solution for reducing dependence on fossil energy because the fossil fuels will run out after a specific period, their production is expensive and they cause environmental problems [1]. The forms of renewable energy can be solar energy, wind energy, water energy and biomass energy. However, now, the most promising new renewable energy is solar energy because solar energy is maintenance-cheap, abundant, having no toxic, free, clean, and having no pollution. Especially, for countries which are tropical and located in the equator line, solar energy is very abundant [2]. The solar energy should be converted first into electrical energy because many appliances use electrical energy to operate. The electronic device that directly converts solar energy into electrical energy is called a solar cell. The solar cell uses photovoltaic effect where a voltage or current is generated when the cell is exposed to light. When a photon with appropriate energy hits a cell consisting p-n junction, by acquiring energy from

photon, an electron moves from one region to another region of the p-n junction and electricity is generated [3]. Generally, the solar cells are divided poly crystalline solar cells, mono crystalline solar cells and thin film solar cells. The mono crystalline and poly crystalline solar cells are fabricated using silicon semiconductor while thin film solar cells are fabricated using cadmium telluride (CdTe), copper indium gallium (di)selenide (CIGS) and amorphous silicon (a-Si) [4]. The mono crystalline solar cell has higher efficiency than polycrystalline solar cell and thin film solar cell has, but is more expensive. The mono crystalline solar cell has higher efficiency because it is pure and defect free [5]. Commonly, the mono crystalline solar cell has black color while polycrystalline solar cell has light or dark blue color. The combination of several solar cells forms a solar panel. The performance of solar panel is very dependent on material, structure and temperature. One obstacle that hampers the operation of solar cell is overheating due to high ambient temperature and excessive solar radiation [6]. Besides that, sand and dust on the surface of solar panel can also greatly affect the performance, especially in desert area [7]. The solar cell is very sensitive to temperature and when the temperature exceeds above permitted value, the performance will degrade. For a mono crystalline and polycrystalline solar cell, the output voltage is a strong function of temperature [8]. Dust on the surface solar panels can reduce the efficiency by 30 % while the high temperature can reduce the efficiency by up to 10 % [9]. The purpose of this research is to improve the performance of solar panel using cooling method. The originality is using submersion method.

Literature review

Electricity is important in many fields such as lighting, heating, cooling and industrialization. Many scientists agree that solar energy is a best candidate to solve energy crisis. The research on paper [16] focuses on improving the solar efficiency by using cooling and cleaning techniques. The system uses a wiper activated by a microcontroller and a sprinkler. The DHT11 is used for measuring temperature and humidity. The study on paper [17] offers solar panel cooling and cleaning device consisting a pole whose the ends are installed by 2 small vehicles and 4 sprays water to sprays water on solar panel and rubber brush for removing dirt and mud. The research on paper [18] concentrates on developing a passive cooling system consisting honeycomb fins made up of aluminum sheet of 0.88 mm thickness.

Materials and methods

Figure 1 shows the schematic of a solar cell and a solar panel. A solar panel is a combination of several solar cells. **Figure 2** shows the schematic of solar irradiation measurement. The measurement was carried out using a solarimeter. The unit of solar irradiation is W/m^2. **Figure 3** shows the schematic of current and voltage measurement of a solar panel. A voltmeter, an ammeter and a variable resistor were used. Two digital multimeters (Sanwa CD800F) were used as voltmeter and ammeter. The infrared thermometer (Benetech GS320) was used to measure the temperature. Solar power meter TM206 was used to measure the irradiance. **Figure 4** shows the schematic of equivalent circuit of a solar cell. An ideal solar cell has 0 R_S and ∞ R_{SH} and the current of solar cell is given by Eq. (1) [10,11]. **Figure 5** shows the methodology of the research. The solar panel was put inside a plastic bag and put inside a container containing water. The experiment was conducted at laboratory of Department of Electrical Engineering on 1 December to 6 December 2022.

The efficiency η and fill factor FF of solar cell are given in Eq. (2) and (3), respectively [12,13]. In particular, the physical properties of the solar panel are shown in the table below.

Table 1 Properties of solar panel used.

Properties	Value
Rated max power	10 W
Current at P_{MAX}	0.58 A
Voltage at P_{MAX}	17.2 V
Short-Circuit Current	0.68 A
Open-Circuit Current	21.6 V
Dimension	$35\times29\times2$ cm^3
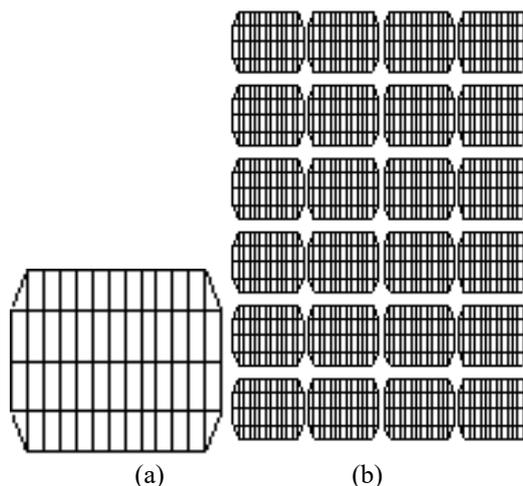
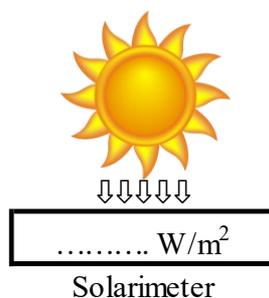**Figure 1** Schematic of (a) solar cell, (b) solar panel.

………… W/m^2

Solarimeter

Figure 2 Schematic of solar irradiance measurement.

SOLAR PANEL or
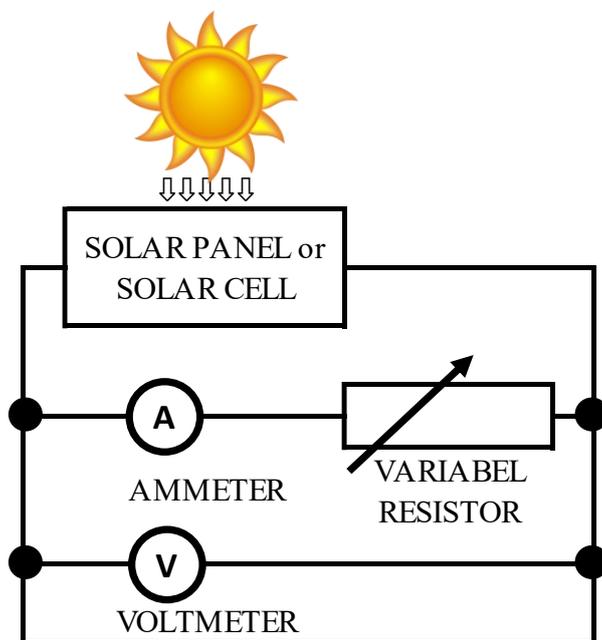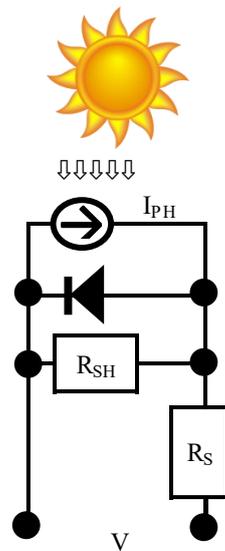SOLAR CELL

A

AMMETER

VARIABEL
RESISTOR

V

VOLTMETER
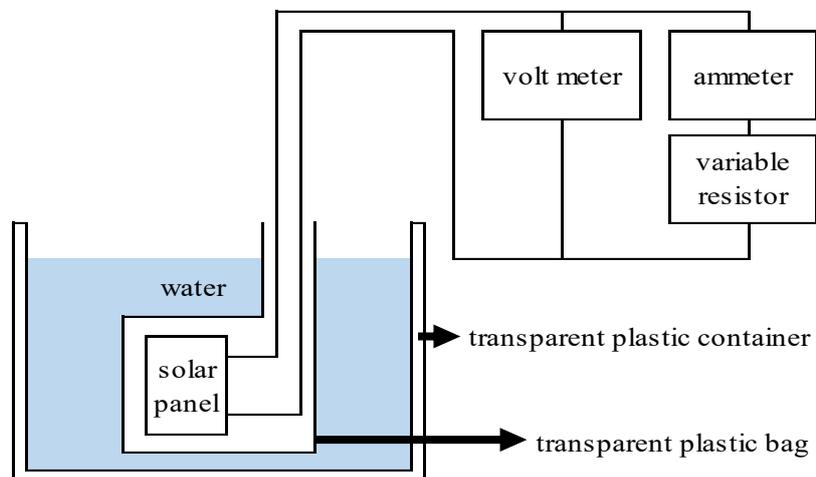
Figure 3 Schematic of voltage and current measurement.

Figure 4 Schematic of equivalent circuit of solar cell.

$$I = I_{PH} - I_S exp\left[\frac{q(V+IR_S)}{nkT}\right] - \frac{V+IR_S}{R_{SH}}\tag{1}$$

$$\eta = \frac{V_{PH}\times I_{PH}}{P_{IN}\times A}\tag{2}$$

$$FF = \frac{V_{MP}\times I_{MP}}{V_{OC}\times I_{SC}}\tag{3}$$


Figure 5 Method of cooling.

Forced ventilation is also a method to decrease the temperature and increase electrical but the cooling fans consume more energy [14]. Therefore, we used submersion cooling method which does not require electrical power in this research.

Results and discussion

Figure 6 shows the measurement result of temperature of solar panel in 1 day. The panel temperature is shown on the vertical axis and the time of a day is shown on the horizontal axis. The temperature

increased slightly from 20.4 ℃ at 2 am to 24.4 ℃ at 6 am in the morning. After that, the temperature increased significantly and reached its maximum point at 48.7 ℃ at 12 am at noon. After 12 am, the temperature decreased rapidly to 24.7 ℃ at 8 pm and decreased slightly again to 23.9 ℃ at 10 pm. By applying cooling method, the temperature decreased from 48.7 ℃ at 12 am at noon to 25.7 ℃.

     Figure 7 shows the measurement result of solar irradiance reaching the solar panel. The solar irradiance in W/m² is shown on the vertical axis and the time of a day is shown on the horizontal axis. The irradiance increased from 0.9 W/m² at 2 am to 144.1 W/m² at 6:30 am in the morning. After that, the irradiance increased rapidly and reached its maximum point at 968.3 W/m² at 12 am. After 12 am, the irradiance decreased rapidly to 56.8 W/m² at 6 pm.
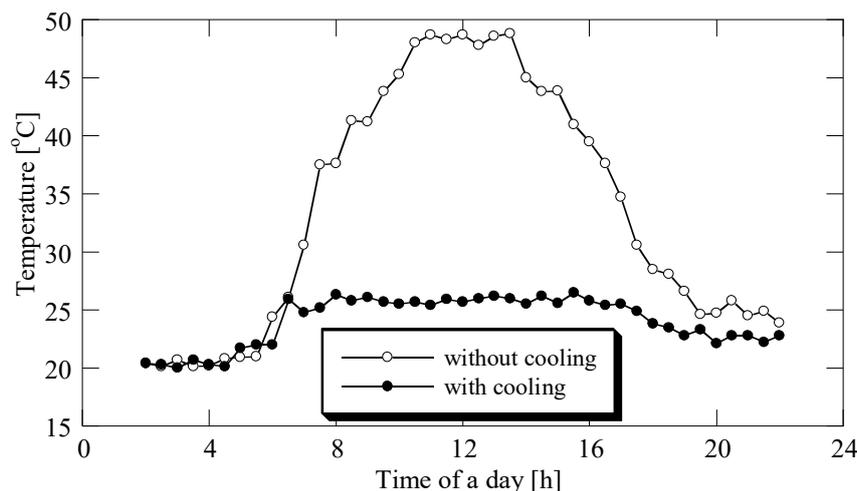
Figure 6 The temperature of solar panel in 1 day.
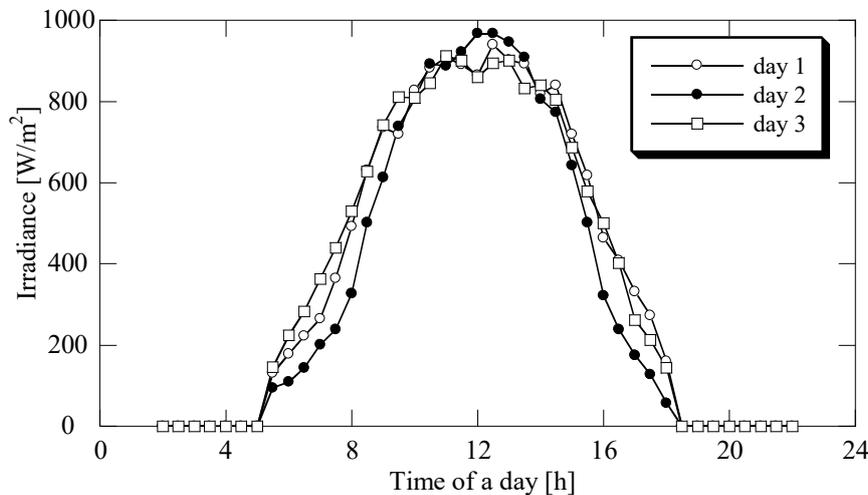
Figure 7 The solar irradiance.

     Figure 8 shows the current versus voltage characteristic without cooling method applied to the solar panel. The voltage of the solar panel is shown on the horizontal axis and the current of the solar panel is shown on the vertical axis. When the solar irradiance increased, the short circuit current (I_{SC}) and the current at maximum power (I_{MP}). The I_{sc} increased from 0.14 to 0.65 A when the irradiance increased from 144.1 to 968.3 W/m². However, because the panel temperature also increased when the irradiance increased, the V_{OC} decreased from 21.42 to 17.91 V. **Figure 9** shows the current versus voltage characteristic with cooling applied to the solar panel. The I_{sc} increased from 0.14 to 0.65 A when the irradiance increased from 144.1 to 968.3 W/m² but the V_{OC} became stable especially at high irradiance after the cooling was applied, the V_{OC} only varied from 20.91 to 21.89 V.

The increasing temperature cause the decrease in the band gap. It can be viewed as increasing the energy of the electrons. Therefore, energy needed to break the bond becomes lower.
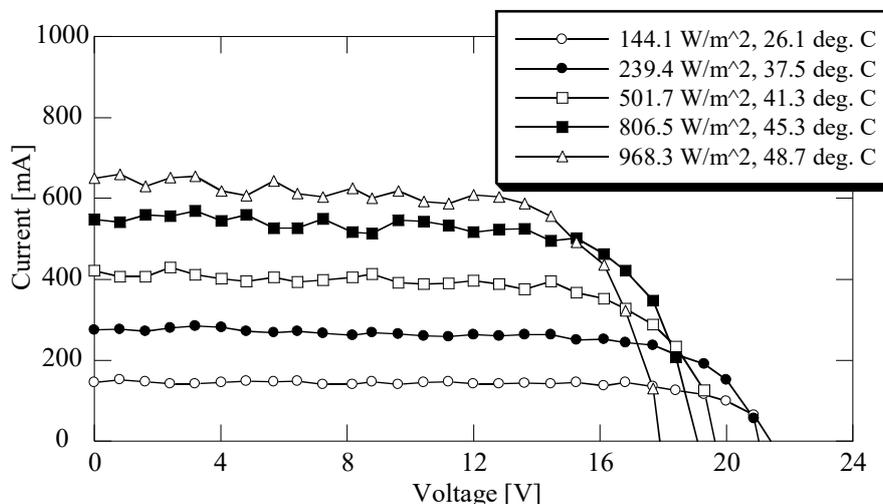

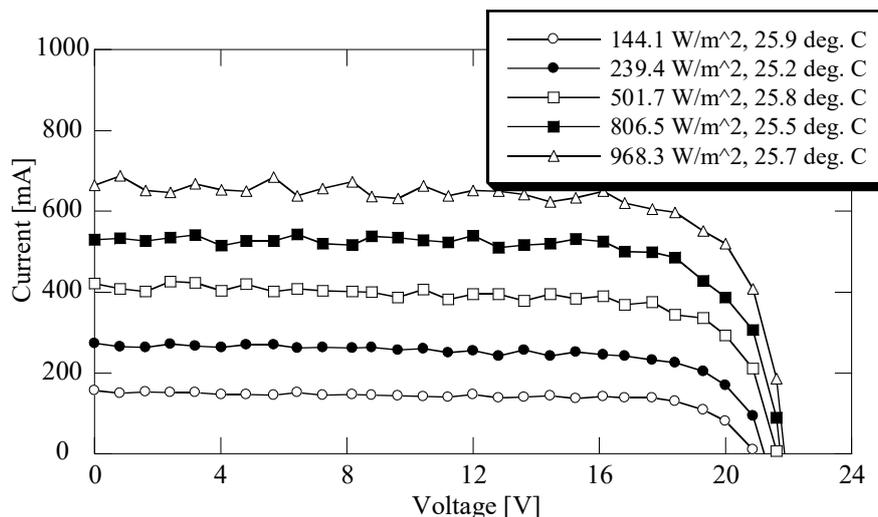**Figure 8** Current versus voltage characteristic without cooling applied.

Figure 9 Current versus voltage characteristic with cooling applied.

Figure 10 shows the power versus voltage characteristic without cooling applied to the solar panel. P_{MP} increased from 2.42 to 8.03 W when the irradiance increased from 144.1 to 968.3 W/m². However, the the V_{OC} decreased from 21.42 to 17.91 V due to rising temperature along with rising irradiance.

Figure 11 shows the power versus voltage characteristic with cooling applied to the solar panel. The P_{MP} increased from 2.44 to 10.99 W when the irradiance increased from 144.1 to 968.3 W/m². Compared to **Figure 10**, after the cooling was applied, the V_{OC} became stable especially at high irradiance. After the cooling is applied, the V_{MP} only varied from 20.91 to 21.89 V. After cooling was applied, the V_{MP} increased and the P_{MP} also increased.

The open-circuit voltage increases when temperature decreases because of reduction of the intrinsic carrier concentration [15].
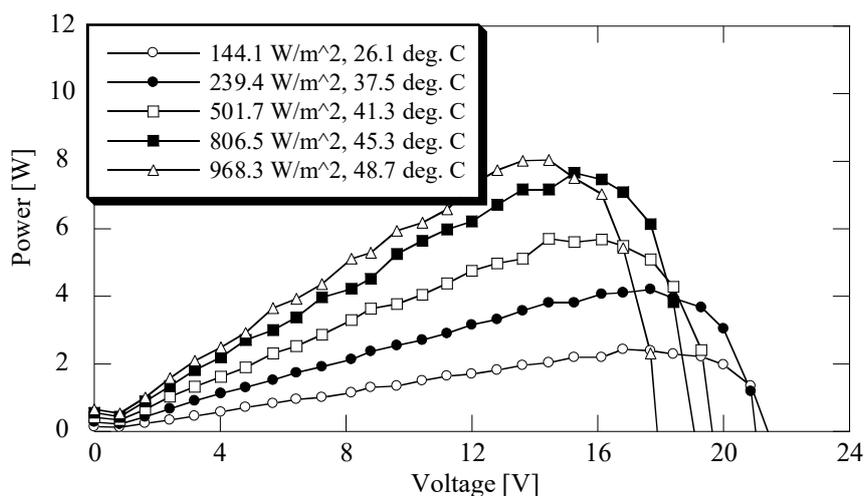
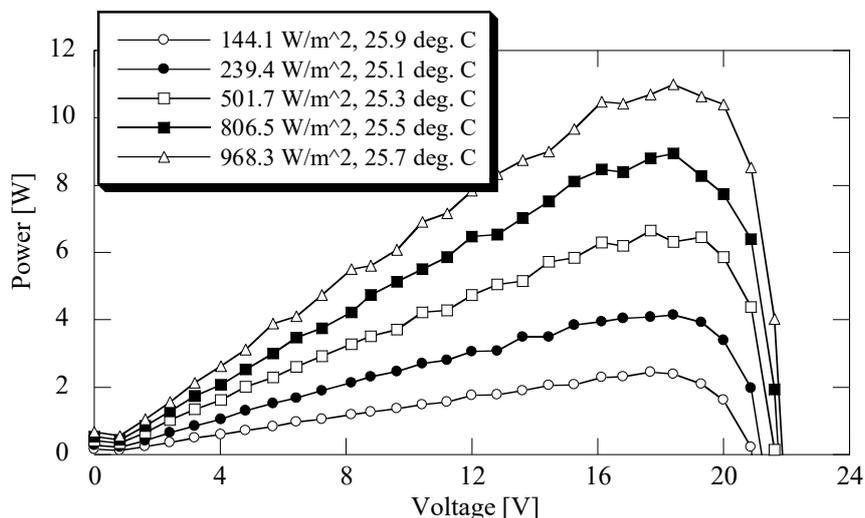**Figure 10** Power versus voltage characteristic without cooling applied.

Figure 11 Power versus voltage characteristic with cooling applied.

Table 1 shows the comparison of this work with other works. Cooling and cleaning techniques using fans, sprinklers and wipers were used and to improve the output in [16] resulting improvement of 34.55 %. Water tank and reservoir were used in [17] and the output increased by 12.4 %. On the other hand, honeycomb fins were used and the efficiency improved by 15 % in [18].

Table 1 Comparison with other works.

Reference	Method	Improvement [%]
[16]	cooling and cleaning techniques	34.55 %
[17]	cooling and cleaning techniques	12.4 %
[18]	cooling under natural condition	15 %
This work	submersion	37 %

Conclusions

The improvement of solar panel output using submersion cooling method has been investigated. The open circuit voltage and the power of the solar panel has increased by applying submersion cooling method. The temperature of the solar panel decreased from around 48.7 °C to around 25.7 °C at irradiance of 968.3 W/m^2. The open circuit voltage also increased from around 17.91 to 21.89 V. The cooling method was by submersion of solar panel. The solar panel was put inside a plastic bag and put inside a container containing water. As the result, the output power of the solar panel increased from 8.02 to 10.99 W. The main problem is conductivity of water. Therefore, coolant with low conductivity is suggested. This submersion method can also be used in larger area such as lakes, rivers, oceans etc. The solar panels are a few cm underwater and installed close to the shore. This method is useful when there are the problems of land requirement. The photovoltaic system can be integrated with the water bodies.

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