2019 3rd INTERNATIONAL CONFERENCE

FIRST

FORUM IN RESEARCH, SCIENCE, AND TECHNOLOGY (FIRST)

CONFERENCE PROGRAMS AND ABSTRACT

The 3rd FIRST 2019 INTERNATIONAL CONFERENCE
FORUM IN RESEARCH, SCIENCE, AND TECHNOLOGY
OCTOBER 09-10, 2019

Palembang, Province of South Sumatera
Indonesia

Organized by :

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PREFACE

The 3rd FIRST 2019 (Forum in Research, Science, and Technology) International Conference was initiated and organized by State Polytechnic of Sriwijaya in collaboration with Management and Science, University (MSU), Malaysia and National Chin-Yi University of Technology, Taiwan. The theme of the conference was "Integration of Advanced Technology to Enhance Social Welfare". The 3rd FIRST 2019 International Conference facilitated the participants from all over the world to meet face to face to open chances in establishing connection and collaboration among them. It was not only for the researchers in academics, but also in industries and governments. This conference became an effective media to link the researchers from many parts of the world conference, for exchanging, sharing, following up and discussing the results of the latest research, industry's needs, and government regulatory policies. The 3rd FIRST 2019 International Conference became worthwhile platform for researchers to present their finding in the areas on multidisciplinary of Engineering and Science (Track 1), Computer Science and ICT (Track 2), and Social Science (Track 3). It has also provided an opportunity for the professionals and researchers to learn and share about the latest development and research in those 3 tracks.

The 3rd FIRST 2019 International Conference attracted so many authors not only from Indonesia but also from other countries, such as Japan, Taiwan, and Malaysia. There were 180 papers were accepted in the 3rd FIRST 2019 International Conference, including 89 papers for Track 1 (Engineering and Science), 46 papers for Track 2 (Computer Science and ICT), and 45 papers for Track 3 (Social Science). In The 3rd FIRST 2019 International Conference, there were 4 keynote speakers and 2 invited speakers. As the keynote speakers, there were Prof. Yasushi Kiyoki, Ph. D from KEIO University, Japan, Prof. Nurul Taufiqu Rochman, M. Eng, Ph. D, From LIPI, Indonesia, Prof. Tjiptohadi Sawarjuwono, M. Ec., Ph. D., Ak, from Universitas Airlangga, Indonesia, and Prof. Win-Jet Luo, from National Chin-Yi University of Technology, Taiwan. As the invited speakers, there were Dr. R. Wisnu Nurcahyo, DVM from Universitas Gadjah Mada, Indonesia, and Assoc. Prof. Dr. Intan Zaurah binti Mat Darus from Universiti Teknologi, Malaysia. The 3rd FIRST 2019 International Conference committee would like to say thank you very much for all the participants and their respected institutions that have supported for the success of the 3rd FIRST 2019 International Conference, and also forall of the guess and sponsors of the 3rd FIRST 2019 International Conference.

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Automatic Cooling of a PV System to Overcome Overheated PV Surface in Palembang

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Abstract. An automatic cooling for a PV panel is necessary to reduce the solar panel surface temperature and to avoid overheating that can lead to the destruction of a PV cell. The automatic design cooling is equipped with a thermostat as the temperature sensor. The automatic cooling consists of a thermostat, a microcontroller to regulate a pump and to flow water on the surface of the solar panel. The reference temperature is set to 36oC, and when the surface temperature exceeds the reference temperature, the pump will flow the water, and the heat is gradually reduced. The pump is off when the surface temperature is less than 36oC. The data application of automatic cooling was taken from 08.30 AM to 03.30 PM. The average power output for automatic cooling is 21.9 W, and the normally installed panel is 19.0 W. The difference in the average output power is 2.9 W. The panel with the automatic cooling system has higher efficiency (3.4%) compared to the normally installed panel (3.0%), with the difference of 0.4%. The application of automatic cooling is economically beneficial due to its output power and efficiency superior compare to the normally installed panel.

1. Introduction

Solar energy has a huge potential to be developed as renewable energy as well as alternative energy to replace fossil energy which is environmentally harmful and increasingly depleting due to the nature of non-renewable energy. Therefore, it is inevitably to find alternative energy to replace fossil energy [1] [2]. Renewable energy is defined as energy produced from natural resources that can be continuously replenished. There are various types of renewable energy, one of which is solar energy. Solar energy has great potential to be a source of electricity

Solar panels generate electrical energy directly using the photovoltaic effect without causing negative impacts on the environment when exposed to solar radiation [3]. Most of the solar energy absorbed by solar panels is converted to heat. The performance of solar panels is very dependent on the operating temperature. In general, solar panels can only convert 4-17% of solar radiation into electrical energy. More than 50% of the sun's energy is converted to heat, and the temperature of the solar panels will increase. The increase in panel temperature will ultimately reduce the electrical energy generated and reduce the efficiency of solar panels, while it can also cause structural damage to solar panels due to the prolonged thermal stress that the solar panels receive [4], [5]. Factors that are greatly affected by this

increase in temperature are a decrease in working voltage, output power, and efficiency, but on the other hand, there is a slight increase in short-circuit current [6].

For this reason, researchers and scientists need to create a panel cooling system that can effectively dissipate heat or heat dissipation so that the optimum working temperature is obtained [7], [8]

Solar panels, like other semiconductor devices, are also susceptible to temperature changes. An increase in temperature will reduce the semiconductor bandgap energy. The decrease in band gap caused by an increase in temperature is the increase in electron energy in the semiconductor material that it takes less energy to cause electron transfer. The parameter of a solar panel, which is strongly affected by temperature rise is the open-circuit Voc voltage [9]. Surface temperature is the primary environmental parameter that affects panel performance which can change its electrical parameters, such as open-circuit voltage (Voc), short-circuit current (Isc), maximum output power (Pmax) and Fill Factor (FF) [10]. The overheated solar panels decrease the efficiency of electrical energy conversion; therefore, this phenomenon should be avoided by cooling down the panel surface to near ambient temperature. Solar panel cooling generally is divided into 2 types, passive and active cooling. Passive cooling is the removal of heat from solar panels naturally or with certain techniques without requiring the use of energy, and active cooling is using equipment and controls that require additional energy to activate the equipment and controller [5], [11].

The conventional media used for cooling solar panels are water and air. In passive cooling, the heat that occurs in solar panels is taken and discharged into the surrounding environment. The design uses air ducts, heat pipes, or heat dissipation fins behind the panel to make the natural circulation of air or liquid flow more efficiently[12]. A discussion of the methods used for passive cooling by using different cooling techniques such as airflow channels, heat pipes, liquids, thermoelectric devices (TE), and Phase Change Materials (PCM) are presented in [13]. One PCM technique that has been developed is the use of phase change materials (PCM) as passive cooling. In a simulation study carried out by conducting PCM techniques were using a water storage tank connected to a pipe to the rear surface of the PV panel. From the simulation, an increase in electricity output of 13.7% compared to those not using PCM [12]. In addition to the type of passive cooling, some researchers currently developed a technique called a radiative cooling technique that is by using a colorless and transparent silicon layer on the surface of the PV panel to produce thermal radiation and reduce the surface temperature of the panel. From the simulation results, there was a decrease in the operating temperature of the panel by 18.3°C, although it was still limited to experiments [14].

The active cooling method results in better efficiency in converting the solar cell to electricity. The design is by removing heat using devices such as fans to force air, and water pumps to drain water to the back or front of the PV panel, by circulating cooling water that flows across a metal pipe tube on which a solar panel is placed, and by spraying water to cooling solar panels. The current method of panel surface cooling is floating solar panels on the water body surface, such as lake [5].

Various types of active cooling systems have been studied and studied, using liquid flow in front of or behind the panel [15]. A study with Mediterranean environmental and climatic conditions using water cooling systems on both sides of the solar panel can increase electricity by 16.3%. Active cooling techniques that use water have a high potential to be implemented; unfortunately, optimization of the water cycle and economic analysis in real applications are still limited [12].

Hybrid Photovoltaic/Thermal (PV/T) solar systems are one of the most popular solar panel cooling system methods today [11]. This hybrid system is a combination of solar panels with a panel surface cooling system with cooling media, that is water or air that is flowed or passed around on the panel surface. Water or air flowing on the solar panels will become warm, which is used for other purposes such as water and warm air for domestic use and others.

The efficiency of solar panels decreases very dramatically if the temperature exceeds the critical temperature. Therefore, it is necessary to keep the panel or cell temperature below this critical temperature. One way to increase efficiency is to drain the panel surface of a thin layer of water. Krauter [16] is one of the researchers who used a thin layer of water that flowed on the surface of the solar panel to reduce heat from solar radiation. The reflection of solar radiation can reduce the efficiency of solar energy conversion to electricity produced by the panel by 8-15%.

Another study is using the Micro Heat Pipe Array cooling system [17]. This cooling system consists of an evaporator and a condenser. The heat from the sun that hits the solar panel will evaporate the liquid in the evaporator, and then the steam is passed into the condenser, and finally, the condenser is cooled using air or water. Using air as a cooler can reduce the temperature of PV panels up to 4.7ºC and increase the efficiency of solar panels by 2.6%. When applying water as a cooler, it can reduce the panel temperature to 8ºC and increase the efficiency of the PV panel by 3%. Therefore it can be concluded that cooling with water is more effective than cooling by using air.

Cooling media commonly used in passive and active cooling are air and water. However, the thermal properties of air make it less efficient as a cooling medium. Therefore, cooling the air is not suitable for absorbing solar panel thermal energy in scorching areas. More electrical energy is needed to operate the fan used to achieve the same performance as water cooling. However, where water is limited, air cooling may still be an option. Cooling with water allows use at higher temperatures, and the use of hot water from the cooling panel in the PV / T system can be used more efficiently. Active cooling systems can also work together with passive cooling to get more effective results. Therefore, the choice of cooling techniques and cooling media is very dependent on the design of the PV-VP system and the conditions under which the system operates [13].

From some literature, the use of water as a cooler turned out to be more effective than using air cooling. Thus, this research aims to build a water-based solar thermal cooling system to solve the problem of overheating solar panels with a minimum amount of water and energy. To minimize the amount of water and energy needed for cooling the solar panel, research is needed to determine at what temperature the PV panel will decrease in efficiency and how long it will take to cool the panel [15].

This paper compares two PV system; the first one is equipped with automatic cooling using a thermostat. Automatic water cooling is used by flowing water on the surface of solar panels as much as 2.5 liters of water per minute by using a mini 4 Watt water pump equipped with a thermostat. The second PV system is installed normally without any cooling devices as the commonly installed PV system. The experiment data are taken from 06.00 AM to 06.00 PM for every 30 minutes. The data result is compared to show the effectiveness of the proposed automatic cooling method in the same conditions and location.

2. Temperature Effects on PV cell

The ideal PV cell can be modelled as an ideal diode where the current source is connected in parallel and added by series connected resistance as shown in Figure 1 [18]:

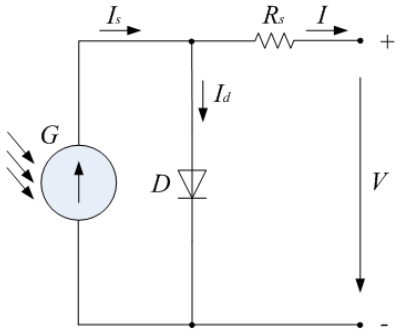

Figure 1. The modelling of an ideal PV cell [18]

The I-V characteristics of ideal PV cell in figure 1 is

$$I = Is - Io\left[e^{\frac{q(V+RsI)}{mkT}} - 1\right] \quad (1)$$

where G is the solar radiance, Is is the photo generated current, Id is the diode current, I is the output current, V is the voltage terminal, Io is the diode reverse saturation current bias, q is the electron charge, m is the diode ideality factor, k is the Boltzman's constant, and T is the cell temperature [19-21].

A PV cell can be characterized by the short circuit current *Isc*, the open circuit voltage is *Voc*. *Isc* is the greatest value of the current generated by the cell is given by

$$Isc = I = Is - Io\left[e^{\frac{q(V+RsI)}{mkT}} - 1\right] \text{ for } V = 0. \quad (2)$$

The open circuit voltage *Voc* is

$$V = Voc = \frac{mkT}{q} ln\left(1 + \frac{Isc}{Io}\right) \text{ for } I = 0. \quad (3)$$

The output power is:

$$P = V\left[Isc - Io\left(e^{\frac{q(v+RsI)}{mkT}} - 1\right)\right] \quad (4)$$

Equation 1 – 4 give the I-V and P-V characteristics for temperature variation between 0 and 75°C, m = 1.66, and are resulted in Figure 2 and 3.

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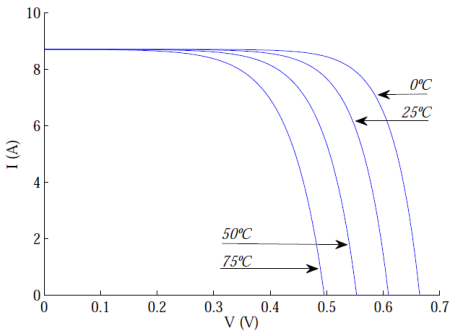

Figure 2. I-V characteristics for the temperature variation between 0 and 75°C

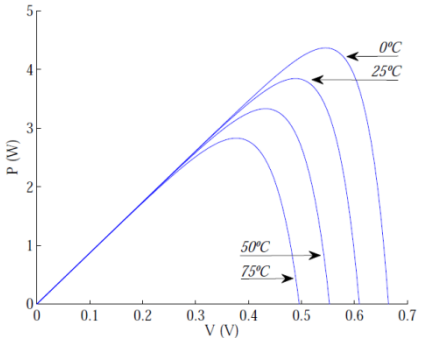

Figure 3. P-V characteristics for the temperature variation between 0 and 75°C

3. Efficiency of PV cell

To determine the efficiency of a solar panel is to compare the maximum power point of P_{MPP} power in the form of FF Fill factor multiplication with V_{MPP} and I_{MPP} with irradiance or solar radiation E, and surface area A of the solar panel. While Fill Factor (FF) is the ratio of pv cell maximum power (P_{MPP}) with Voc and Isc, which all of the parameters can be seen in Figure 4.

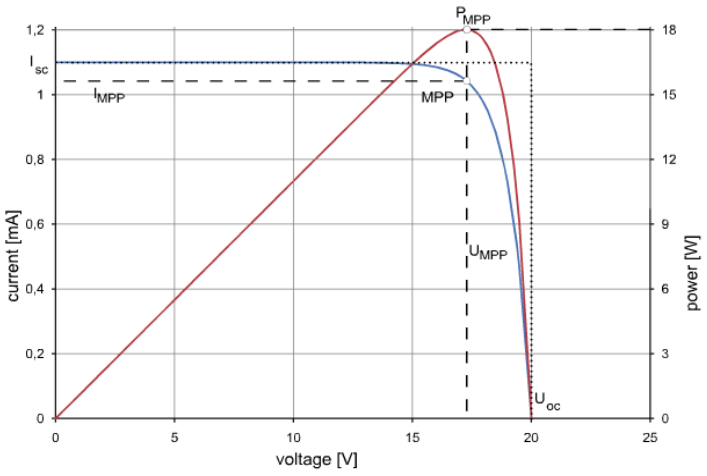

Figure 4. Fill Factor (FF) of a PV cell

The Fill Factor of a PV cell is given by:

$$FF = \frac{P_{MPP}}{V_{OC} \cdot I_{SC}} = \frac{V_{MPP} \cdot I_{MPP}}{V_L \cdot I_{SC}} \quad (5)$$

The efficiency of a PV cell is given by:

$$\eta = \frac{P_{MPP}}{E \cdot A} = \frac{FF \cdot V_{MPP} \cdot I_{MPP}}{E \cdot A} \quad (6)$$

P_{MPP} is the maximum power point in watt, E is Irradiance or solar radiation in Watt/m^2, and A is the surface area of pv cell in m^2

4. Experimental setup

The study was conducted in Palembang, Indonesia located in 2° 59'27.99 "S and 104° 45'24.24" E. The experimental setup is using 2 polycrystalline 100 WP panels. The cooling of the PV panel surface is carried out letting the water drain using a mini 4 Watt water pump which pumps 2.5 liters of water per minute equipped. The system is equipped with a thermostat as a temperature sensor. The second PV panel was installed typically without any cooling devices. The study was conducted from 06.00 AM to 06.00 PM, and data were collected per half hour. The data results from both experiment setup are compared, which operated in the same conditions and locations. Figure 5 shows the schematic diagram, and figure 6 shows the actual experimental setup.

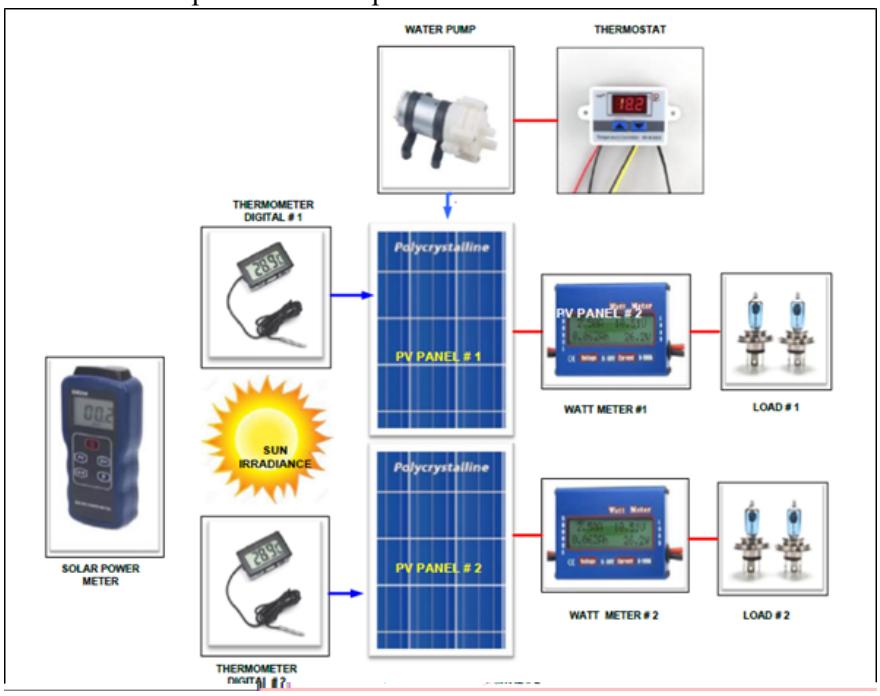

Figure 5. Diagram hubungan peralatan experiment

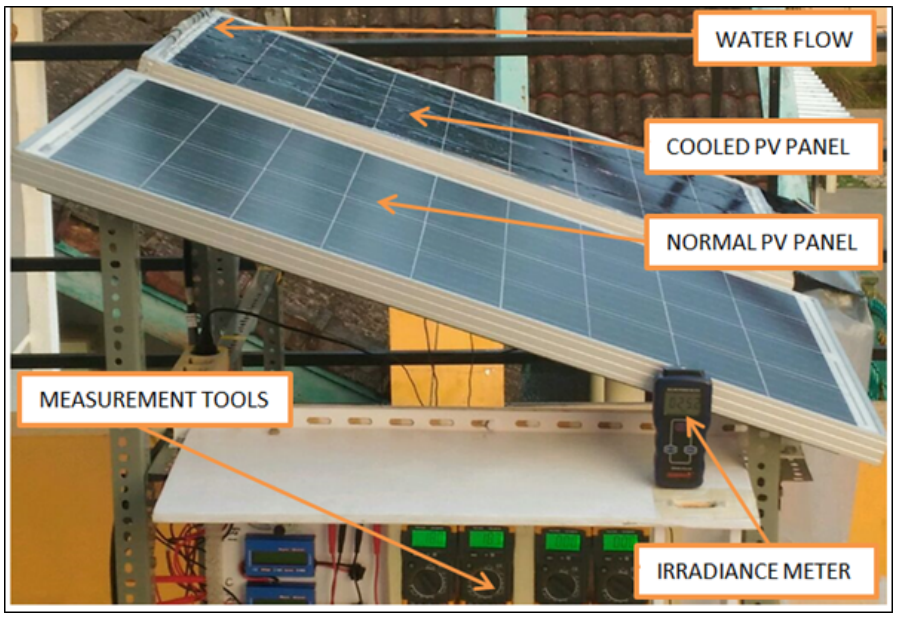

Figure 6. The actual experimental setup

5. Result and discussion

The objective of this research is an automatic cooling system for PV panels to reduce overheating and increase the efficiency of electrical energy conversion. A thermostat is installed as a temperature sensor to detect the overheated condition. If the PV panel surface temperature is more than the tolerate temperature (36^{o}C), the thermostat gives the input "1" to the microcontroller which will turn on the water pump and water flows on the surface of PV panels. As the temperature is decreasing up to the tolerate one, the microcontroller will turn the pump off to save energy. The data was taken on May 4, 2019.

The effect of surface temperature PV panel output voltage is given by in Figure 7, which shows the difference in output voltage between the normally installed and the cooled PV panel. The average difference between the two output voltages is 1.5 V. The highest temperature difference between the two panels is 23.5^{o}C which occurs at 12.00 WIB, and the difference in average temperature difference between the two panels is 9.9^{o}C. This picture also shows that the solar panel effectively starts to generate electricity more than 12 V, starting around 08.30 AM. At this point, the water pump also starts ON to cool the panel surface, because the surface temperature of the panel has exceeded the temperature set point on the thermostat, which is 36^{o}C. At 04.30 PM, the water pump started to turn OFF because the panel surface had begun to cool, and the output voltage of the solar panel also began to decline.

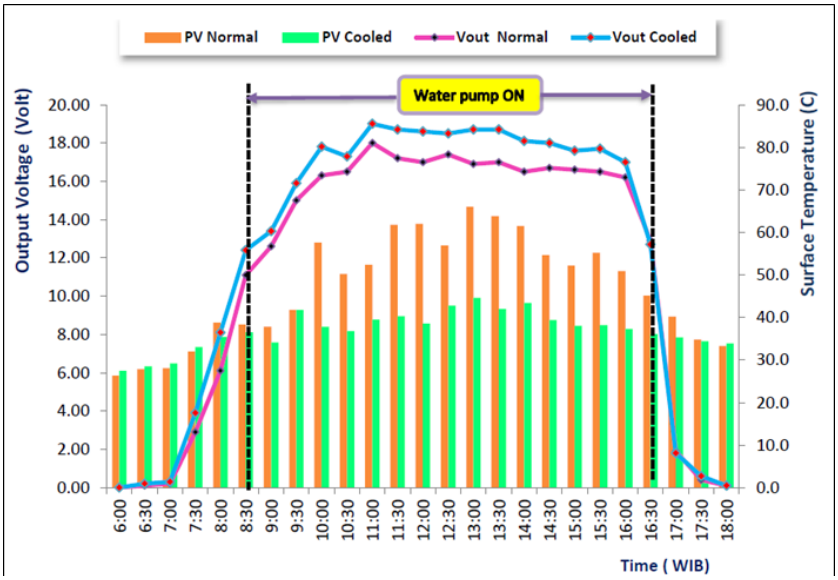

Figure 7. Effect of changes in surface temperature on Output Voltage

The effect of changes in surface temperature on the output power of solar panels can be seen as in Figure 8, which shows the difference in output power between normally installed PV panels and the cooled PV panel. Figure 8 shows that around 8.30 AM, the water pump also starts to ON to cool the panel surface because the surface temperature of the panel has exceeded the set point on the thermostat, which is 36°C. At 04:00 PM, the water pump is turned OFF because the panel surface had begun to cool off, and the output power coming out of the panel also began to decrease. The average output power produced by water-cooled solar panel is 21.9 W while the installed output power of the normally installed panel is 19.0 W. The average difference between the two output power is 2.9 W.

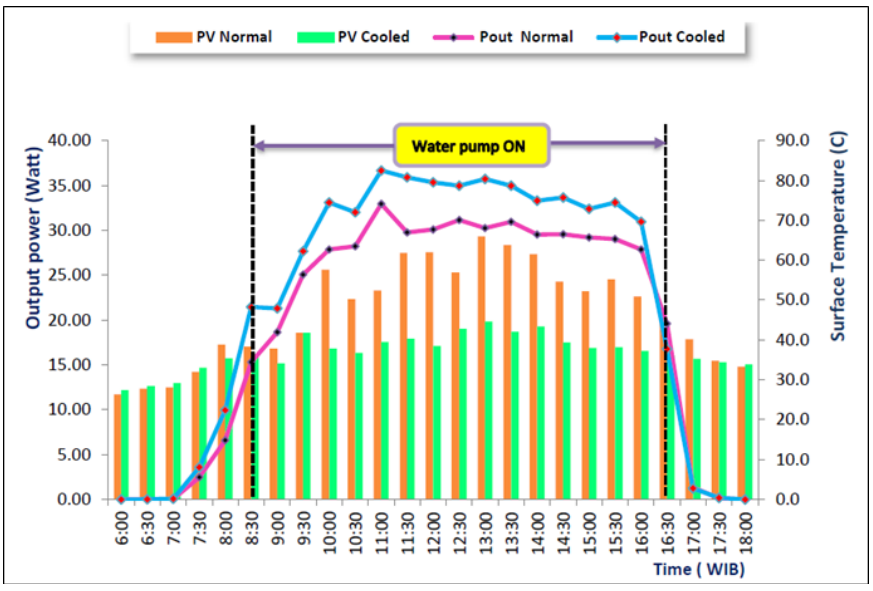

Figure 8. Effect of changes in surface temperature on Output Power

Comparison of efficiency between normally installed and cooled solar panels when the load is applied to determine the characteristics of PV panels calculated using equation (6). Factor fill FF is 0.7 and the surface area of the PV panel (A) is 660 mm x 1125 mm taken from the panel specification technique.

The efficiency is shown in Figure 10 which appears that the efficiency of the two PV panels will begin to increase in the time interval between 08.30 AM and 03.30 PM. The average efficiency of PV panels cooled with water is higher by 0.4% compared to PV panels installed normally. The average efficiency of PV panels that are water cooled is 3.4%, the average efficiency that is installed normally is 3.0%. At the time interval between 08.30 AM and 03.30 PM, the highest efficiency for water-cooled PV panels is 7.13% which occurs at 09.30 AM, while the normal installed PV panel with the highest efficiency is 6.46% which occurs at the same time.

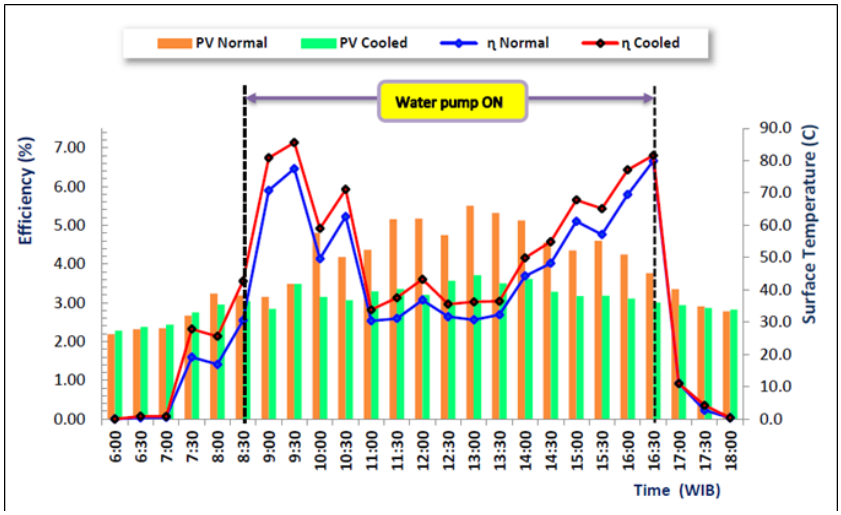

Figure 9. Efficiency comparison of normal and cooled solar panel.

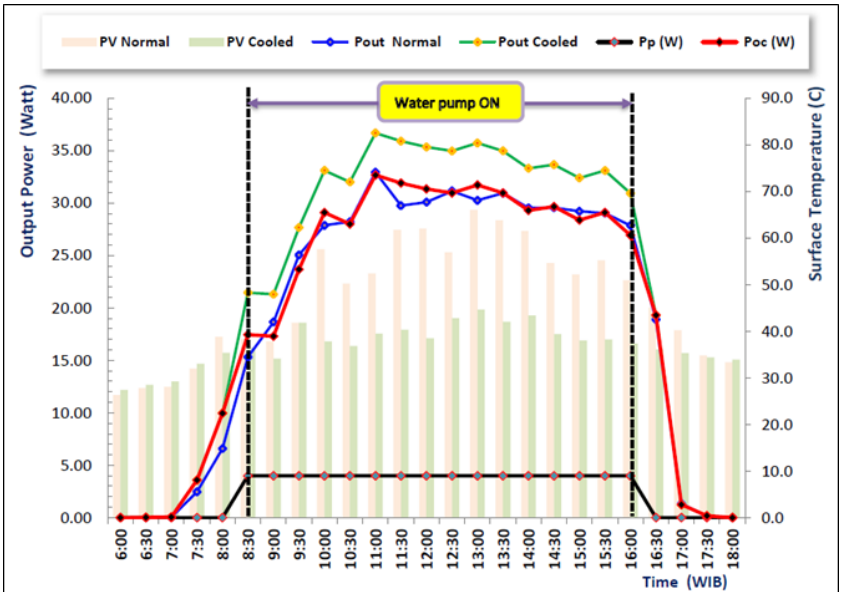

Figure 10. Daya netto yang dihasilkan PLTS

Note:

P_{out} Normal	: Output power of normal installed solar panel
P_{out} Cooled	: Output power of normal cooled solar panel
Pp	: Power required to turn on the pump.
P_{oc}	: Net Output power of normal installed solar panel and cooled PV panel ($P_{oc} = P_{out\ Cooled} - Pp$)

Δ : The difference between the normal power and Net power

The cooling system installed in this study utilized water to cool down the PV panel surface, this method requires power to turn a pump. However, based on the difference of the output power produced by the normal installation and the cooled one. The proposed method is economically advantage with Poc 19.31 W compared to $P_{out\ normal}$ 19 W. The difference is 0.31 W.

6. Conclusion

This study designs an Automatic Cooling of a PV System to Overcome Overheated PV Surface in Palembang. This automation is made possible by the installation of a thermostat as a temperature sensor. The temperature detected by thermostat becomes the input to the microcontroller to turn on/ off the water pump automatically. Thermostats work based on temperature settings derived from data in previous studies obtained 36oC temperature settings. The water pump is OFF when the solar panel surface temperature is still below 36oC, and ON if the panel surface temperature is more than 36oC. The temperature regulation at the work of the water pump can increase the efficiency of using electric power to drive the water pump, as evidenced by the water pump starts ON around 08.30 AM and OFF after 03.30 PM. The average output power of water-cooled PV Panel is 21.9 W, the output power of PV Panel installed normally is 19.0 W. Difference The average output power of 2.9 W. Water-cooled PV Panel has a higher efficiency compared to normally installed PV panel, which is 0.4%. The average efficiency of a water-cooled PV Panel is 3.4%, while the average efficiency of a normally installed PV Panel is 3.0%. The use of automatic water cooling is 19.31 W compared to the power generated by a normally installed PV Panel, which is19 W; therefore, the difference (Δ) is 0.31 W.

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