Water Cooling on 30 Watt-peak Solar Panel

Anak Agung Ngurah Gde Sapteka
Department of Electrical Engineering
Politeknik Negeri Bali
Denpasar, Indonesia
sapteka@pnb.ac.id

Anak Agung Ngurah Made Narottama
Department of Electrical Engineering
Politeknik Negeri Bali
Denpasar, Indonesia
narottama@pnb.ac.id

I Nyoman Sugiarta
Department of Electrical Engineering
Politeknik Negeri Bali
Denpasar, Indonesia
sugiartapnb@gmail.com

I Ketut Ta
Department of Electrical Engineering
Politeknik Negeri Bali
Denpasar, Indonesia
iketutta@pnb.ac.id

Purnomo Sidi Priambodo
Department of Electrical Engineering
Universitas Indonesia
Depok, Indonesia
pspriambodo@gmail.com

Nandy Setiadi Djaya Putra
Department of Mechanical Engineering
Universitas Indonesia
Depok, Indonesia
nandyputra@eng.ui.ac.id

***Abstract*—The purpose of writing this article is to find out the power reduction per degree Celsius in a 30 Wp solar panel and the effort to handle it through water cooling. The solar panel is placed on a vertical holder with a hose is mounted on top side of the solar panel. The hose is perforated every 10 cm to drain the water to the front side of solar panel. Two units of halogen lamp of total 600 Watt are used to irradiate and heat the surface of solar panel. The halogen lamps are positioned in front of the solar panel at 32 cm. Three units of thermocouples are attached at front side and three units at back side of solar panel to measure temperatures. Besides, we measure the ambient temperature using a unit of thermocouple. The data of temperatures are collected using NI cDAQ-9174 hardware and LabView software. The average value of low temperature is 39.62 ^{o}C and the average value of high temperature is 61.39 ^{o}C, while these values correspond with the maximum output power of 7.13 W and 6.59 W, respectively. The power will decrease at magnitude of 0.025 W/ ^{o}C. Therefore, water cooling on the surface of solar panel can decrease temperature and increase power output.**

***Keywords*—water cooling, solar panel, temperature, power.**

I. INTRODUCTION

As stated by previous researcher, the operating temperature plays a central role in the photovoltaic conversion process. Both the electrical efficiency and hence the power output of a solar panel depends linearly on the operating temperature, decreasing with increasing the solar panel temperature [1]. For crystalline silicon-based solar panel devices, as the operating temperature of the panel increases, the efficiency decreases. Higher operating temperatures also lead to accelerated material and mechanical degradation, potentially compromising system effectiveness over the lifetime of the panels [2]. In 2016, Nizetic *et al*. proposed and tested a water spray cooling technique on a monocrystalline photovoltaic panel for different cooling circumstances (regimes). The best cooling option turned out to be simultaneous cooling of front and backside solar panel surfaces [3]. The efficiency drops with the rise in temperature, with a magnitude of approximately 0.5%/ºC. Several cooling techniques have been tried, mostly based on active water and air cooling, as these are the simplest techniques [4]. In 2017, the Energy, Vibration and Sound Research Group of Universiti Kebangsaan Malaysia compared the output power and efficiency between continuous cooling system, cooling system every hour and non-cooling system of solar panel. The output power calculated for the continuous cooling system was 68.8 Watt, cooling system every hour was 65.11 Watt and 59.06 Watt for non-cooling system respectively [5].

In this paper, we report our experiment, result and analysis about water cooling on 30 Watt-peak polysilicon solar panel. Instead of using natural outdoor sunlight, we do experiment in laboratory, by applying 2 × 300 Watt halogen lamps as controllable light source and thermal heater at the same time. The experiment shows clearly how the increasing solar panel surface temperature will decrease the solar-cell output power.

II. METHODOLOGY

In this research, a 30 Watt-peak solar panel is heated by using two units of 2 × 300 Watt halogen lamps and cooled by drained water at the front side. The halogen lamps are positioned at 32 cm away from solar panel and placed on a vertical holder, meanwhile the water is drained from a perforated host. We have conducted several experiments of water cooling at Laboratory of Physics, Politeknik Negeri Bali, Indonesia. In each experiment, seven temperature data are collected by using thermocouples. The thermocouples are located at front-left panel, front-center panel, front-right panel, back-left panel, and back-center panel. The experiment setup is shown in Fig. 1.

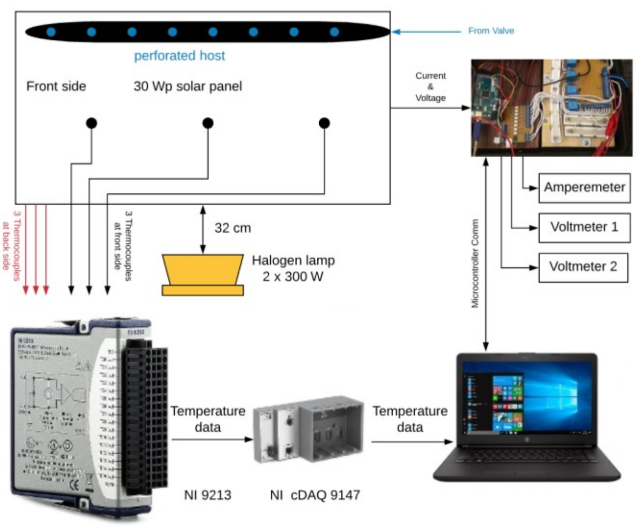

Fig. 1. Experiment setup.

One addition thermocouple is also used to collect the ambient temperature. These thermocouples are connected to

978-1-5386-7548-9/18/$31.00 ©2018 IEEE

the NI cDAQ-9174 hardware and LabView software. An electronic circuit is also used to collect the voltage and current data at different temperature. This circuit is controlled by a microcontroller.

To analyze the data, the average value on the entire surface of solar panel is calculated. The voltage and current data are smoothed by using Boltzmann Sigmoid Function (BSF) to find the maximum power point. We show that there is no significant difference between the measurement data of various irradiance and temperature levels with the BSF results [6]. The conclusion is taken from result and analysis of the maximum power point at different temperature.

III. Result and Discussion

A. *Result*

In this research, we have conducted five experiments of water cooling on 30 Watt-peak solar panel at Laboratory of Physics, Politeknik Negeri Bali, Indonesia. Temperature, voltage and current data are collected in the experiments and shown in the following results.

- Result of the first experiment.

  Solar panel is heated by the halogen lamps from the beginning to the end of experiment 21600 second (6 hours) as shown in Fig.2. The front panel then cooled by water from 7200th to 14400th seconds and afterward from 18000th to 21600th seconds. The temperature data is shown on Fig. 2.

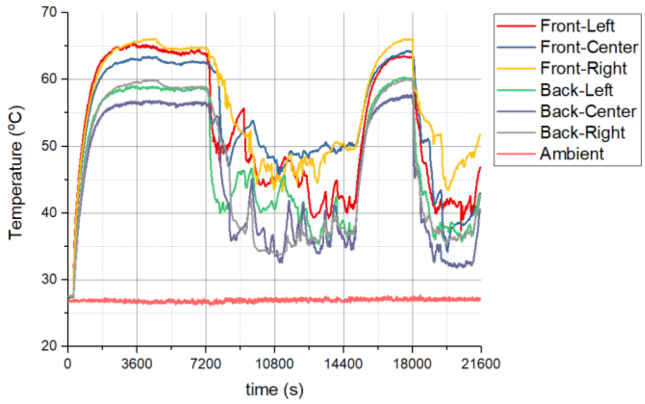

Fig. 2. Temperature of solar panel of the first experiment.

- Result of second experiment

  Solar panel is heated by the halogen lamps from the beginning to the end of experiment 21600 second (6 hours), similar to the first experiment. The front panel is then cooled by water from 7200th second to 8682th seconds, from 12330th to 12957th seconds, from 14933th to 15617th seconds, from 17782th to 18427th seconds and from 20283th to 20634th seconds. The temperature data is shown on Fig. 3.

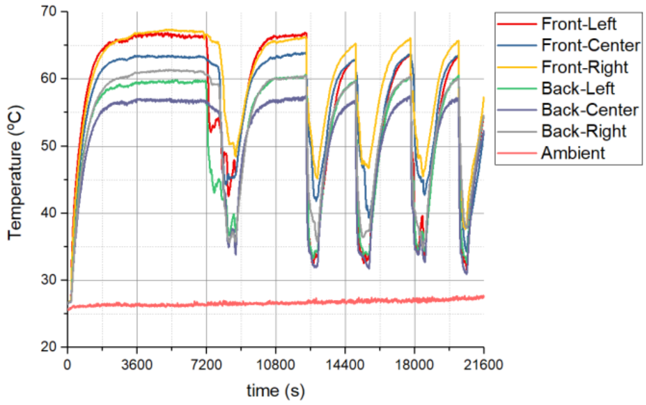

Fig. 3. Temperature of solar panel of the second experiment.

B. *Discussion*

To analyze the effect of water cooling, the average temperature value of entire solar panel surface is calculated, and the voltage-current data is smoothed using Boltzmann Sigmoid Function (BSF). The following figures are used to analyze these phenomena.

At first experiment, the average temperature increases and decreases as shown in Fig. 4 by controlling the flow of water.

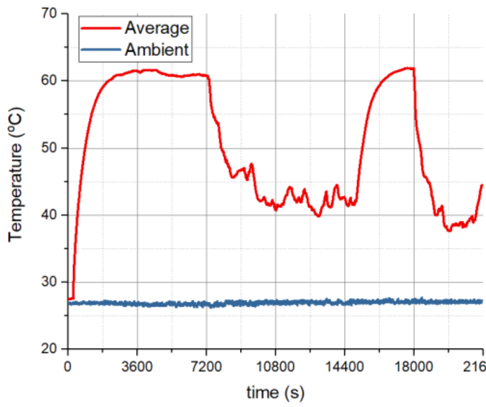

Fig. 4. Average temperature of solar panel of the first experiment.

Current (I) and Voltage (V) characteristic data of solar panel are collected at 7242th second, 12710th second, 16724th second and 19806th second with average temperature of 60.70 °C, 40.75 °C, 60.91 °C, and 37.73 °C respectively as shown in Fig. 5.

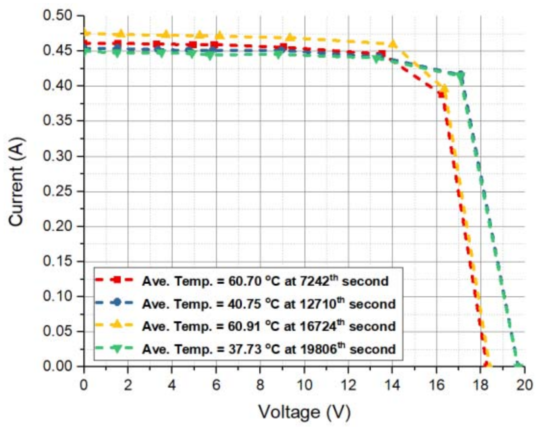

Fig. 5. I-V characteristic of the first experiment.

Then the I-V characteristic is fitted using BSF as shown in Fig. 6. From the BSF fit data of I-V characteristic, the P-V characteristic is calculated as shown in Fig. 7. When the average temperature is decreasing from 60.70 ºC to 40.75 ºC, then the maximum power point is increasing from 6.56 W to 7.14 W. When the average temperature is increasing from 40.75 ºC to 60.91 ºC, then the maximum power point is decreasing from 7.14 W to 6.76 W. When the average temperature changing from 60.91 ºC to 37.73 ºC, then the maximum power point is increasing from 6.76 W to 7.09 W.

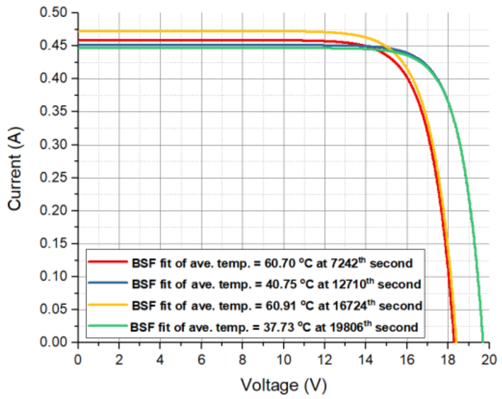

Fig. 6. BSF fit of I-V characteristic of solar panel of the first experiment.

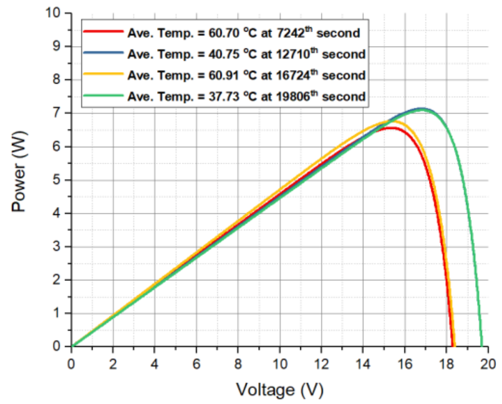

Fig. 7. P-V characteristic of solar panel of the first experiment.

At second experiment, the average temperature is increased and decreased as shown in Fig. 8 by controlling the flow of cooling water. Current (I) and Voltage (V) data of solar panel are collected at 2614th, 8659th, 12329th, 12912th and 14893th seconds with average temperature of 61.66 ºC, 42.26 ºC, 62.60 ºC, 37.73 ºC and 61.08 ºC respectively as shown in Fig. 9.

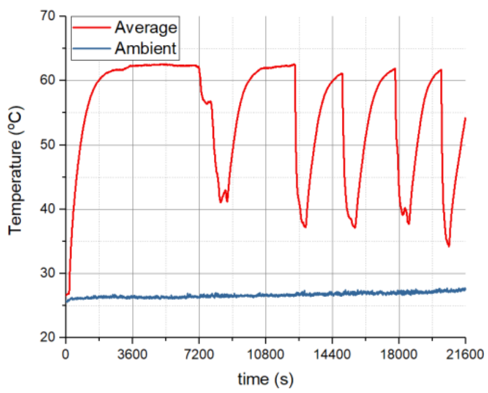

Fig. 8. Average temperature of solar panel of the second experiment.

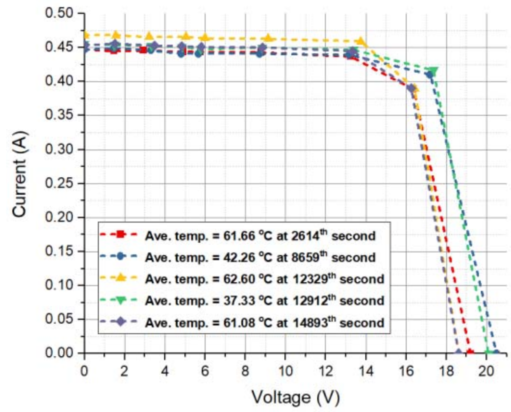

Fig. 9. I-V characteristic of solar panel of the second experiment.

I-V characteristic is fitted using BSF as shown in Fig. 10. From the BSF fit data of I-V characteristic, the P-V characteristic is calculated as shown in Fig. 11. When the average temperature is decreasing from 61.66 ºC to 42.26 ºC, the maximum power point is increasing from 6.44 W to 7.04 W. When the average temperature is increasing from 42.26 ºC to 62.60 ºC, then the maximum power point is decreasing from 7.04 W to 6.70 W. When the average temperature is decreasing from 62.60 ºC to 37.33 ºC, then the maximum power point is increasing 6.70 W to 7.26 W. When the average temperature is increasing from 37.33 ºC to 61.08 ºC, then the maximum power is decreasing from 7.26 W to 6.50 W.

From both experiments and P-V characteristics, the average temperature and the maximum power point is tabulated in Table I. The average value of low temperature is about 39.62 ºC and the average value of high temperature is about 61.39 ºC, while it corresponds to the maximum output power values of 7.13 W and 6.59 W, respectively, as shown in Fig. 7 and Fig. 11. By using these values, the power will decrease at magnitude of 0.025 W/ ºC.

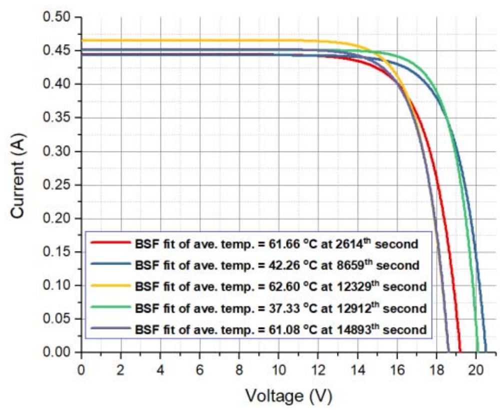

Fig. 10. BSF fit of I-V characteristic of solar panel of the second experiment.

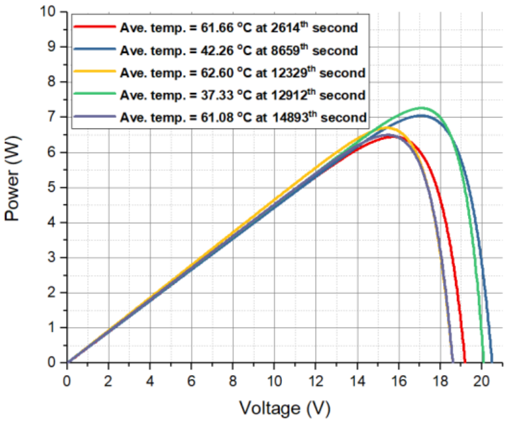

Fig. 11. P-V characteristics of solar panel of the second experiment.

TABLE I. AVERAGE TEMPERATURE AND MAXIMUM POWER POINT

Experi-ment	Ave. Temp. (°C)	Max. Power Point (W)	Δ Temp. (°C)	Δ Max. Power Point (W)
1	60.70	6.56	-	-
	40.75	7.14	- 19.95	0.58
	60.91	6.76	20.16	-0.38
	37.73	7.09	-23.18	0.33
2	61.66	6.44	-	-
	42.26	7.04	-19.4	0.6
	62.60	6.70	20.34	-0.34
	37.73	7.26	-24.87	0.56
	61.08	6.50	23.35	-0.76

IV. CONCLUSION

We report our experiment, result and analysis of water cooling on 30 Watt-peak polysilicon solar panel by applying 2 × 300 Watt halogen lamps as controllable light source and thermal heater at the same time. The experiment shows clearly that the increasing solar panel surface temperature will decrease the solar panel power output. In other words, increasing solar cell temperature will decrease the solar cell output power. From the experiments, the power will decrease at magnitude of 0.025 W/°C. Therefore, water cooling on the surface of solar panel can decrease temperature and increase power output.

ACKNOWLEDGMENT

This research is supported and financed by the Directorate of Research and Community Service, Ministry of Research and Higher Education, Republic of Indonesia, grant number DIPA-042.06.401516 in 2018 for post doctoral research program. We are also assisted by Central of Research and Public Service, and Department of Electrical Engineering, Politeknik Negeri Bali, Indonesia. We also would like to thank to Dr. I Wayan Nata and Mr. Wayan Darma Wirahadi for supporting our research group.

REFERENCES

[1] E. Skoplaki and J. A. Palyvos, "On the temperature dependence of photovoltaic module electrical performance: A review of efficiency / power correlations," *Sol. Energy*, vol. 83, no. 5, pp. 614–624, 2009.

[2] M. K. Smith *et al.*, "Water cooling method to improve the performance of field-mounted, insulated, and concentrating photovoltaic modules water cooling method to improve the performance of field-mounted, insulated, and concentrating photovoltaic modules," *J. Sol. Energy Eng.*, vol. 136, no. August, pp. 1–4, 2014.

[3] S. Nizetic, A. Yadav, and F. Grusibic-Cabo, "Water spray cooling technique applied on a photovoltaic panel: The performance response," *Energy Convers. Manag.*, vol. 1, no. January 2016, pp. 1–32, 2016.

[4] F. Grubisic-Cabo, S. Nizetic, and T. G. Marco, "Photovoltaic panels: A review of the cooling," *Trans. Famena XL*, vol. 1, no. 1, pp. 63–74, 2016.

[5] K. Sukarno, A. S. A. Hamid, H. Razali, and J. Dayou, "Evaluation on cooling effect on solar PV power output using laminar H2O surface method," *Int. J. Renew. Energy Res.*, vol. 7, no. 3, pp. 1213–1218, 2017.

[6] A. A. N. G. Sapteka, A. A. N. M. Narottama, A. Winarta, K. A. Yasa, P. S. Priambodo, and N. Putra, "Modelling of electric characteristics of 150-watt peak solar panel using boltzmann sigmoid function under various temperature and irradiance," *IOP Conf. Ser. J. Phys. Conf. Ser. 953*, vol. 1, no. 1, pp. 1–11, 2018.