

A Study of Heat Pipe as Thermal Management on 30 Wp Solar Panel

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Abstract—This paper discusses the application of copper pulsating heat pipe as passive thermal management on solar cell panel. In this study, an analysis of 30 Wp polycrystalline solar panel surface temperature with heat pipe is discussed. A 1000 W halogen lamp is used to illuminate and heat the solar panel indoor at 50 cm distance. To measure the surface temperature of solar panel, six thermocouples are installed at different positions. On the heat pipe, five thermocouples are installed at various positions. The heat pipe is mounted on the back-center of the solar panel. The passive thermal management using heat pipe shows that there is a decrease in the average surface temperature of the solar panel by 6.33 °C. Thus, the heat pipe can be used as passive thermal management on 30 Wp solar panel.

Keywords—heat pipe; power, solar panel; temperature; passive thermal management.

I. INTRODUCTION

Photovoltaic effect was originally observed by Alexandre-Edmond Becquerel in 1939 which turned solar energy into electricity via an electrode in a conductive solution exposed to light [1]. Furthermore, solar cell technology developed in modern era, starting from a system that only stand alone with an output of only a few Watts and now became a system with several Mega Watts connected to the electricity network using silicon-based semiconductor. The reports from researchers regarding solar panels indicate that there are constraints in terms of the efficiency of the power produced related to working temperature. The results show a decreasing in the efficiency of solar panels related to the increasing operating solar cell temperature. The active cooling solar cell research has been conducted by many researchers, in order to improve solar cell efficiency by decreasing working temperature. An experiment of active cooling using a parallel array of ducts with inlet / outlet manifold to distribute the airflow at the back

of solar panel shows that the temperature drops significantly and leads an increase efficiency of solar panel to between 12% and 14% [2]. Another experiment of active cooling using water immersion technique shows that the solar panel efficiency has increased by about 11% at water depth of 6 cm [3]. For concentrated photovoltaic (CPV) under water cooling, the temperature reduces under 60 °C and the efficiency of CPV increases and produces more electric power output [4]. Based on the results of the experiment under water cooling, it was found that solar panel yield the highest output energy when it reaches a maximum allowable temperature of 45 °C [5]. Other researcher uses solar-driven rainwater cooling system. This system is able to pump 152 L of water to solar panel modules. The temperature of the module reaches 19 °C and average electrical yield is increased by 8.3% [6]. Active cooling can improve efficiency, however, it requires energy from the outside for the cooling process. This cooling process improves efficiency, however, simultaneously it decreases efficiency since it needs additional supply. Other researchers reported passive cooling of solar panel. An experiment of passive cooling is conducted with the help of fins at the back surface of the solar panel, where the raises temperature of solar panel can be reduced. The fins absorb the heat that makes operating temperature of solar panel drops significantly about 4.2% and the power output increases 5.5% [7]. Another experiment of passive cooling is conducted using novel hybrid-structure flat plate (NHSP) heat pipe for a CPV. The uses of an NHSP copper-based heat pipe shows the increases of photoelectric conversion efficiency by approximately 3.1%, compared to an aluminum substrate [8]. The other researchers observed the output of CPV with heat pipe cooling system using working fluid of acetone. It is found that when the temperature of the solar panel is reduced by some means the efficiency is being increased [9].

In this paper, we report our experiment, result and analysis about heat pipe as passive thermal management on 30 Watt-peak polysilicon solar panel. Instead of using natural outdoor sunlight, we do experiment in laboratory, by applying 1000 Watt halogen lamps as controllable light source and thermal heater at the same time. The experiment shows that using heat pipe, the solar cell temperature can be decreased from average temperature of 74.08 °C to 68.25 °C.

II. METHODOLOGY

We design a copper-based heat pipe with outer diameter of 2.88 mm, inner diameter of 1.40 mm, and overall length of 2.875 m. The evaporator is fitted with a metal plate with thickness of 0.4 mm and dimension of 5 cm × 12 cm as the heat absorption area. The metal plate is mounted at the back-center of 3500 cm² solar panel area. The condenser is equipped with 10 units of fin separated 1 cm apart. The fins are made of copper with 2.5 mm diameter. Figure 1 shows the design of pulsating heat pipe. The heat pipe is filled with 2.2 mL of methanol working fluid under vacuum condition, as a 50% of total heat pipe volume.

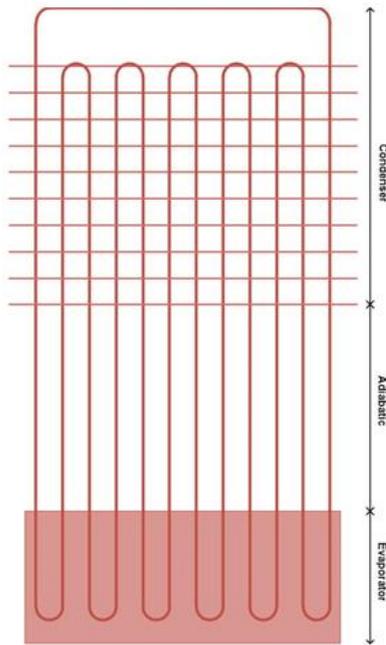


Fig 1. The design of heat pipe

The temperatures data are collected by using K-type thermocouple at six points on solar panel surface, *i.e.*, at the front-right, front-center, front-left, back-right, back-center and back-left of solar panel. On the heat pipe, temperatures data are collected two points at the condenser, one point at the adiabatic and two points at the evaporator. The temperatures data is collected using cDAQ-9147, NI 9213 hardware and Lab View software of National Instrument. A computer is used to control the cDAQ-9147 and the Arduino Mega microcontroller. As source of indoor light and heat, a 1000 W halogen lamp is used in the distance of 50 cm from the solar panel. The data is collecting for 6 hours or 21600 seconds. Figure 2 shows the experiment setup.

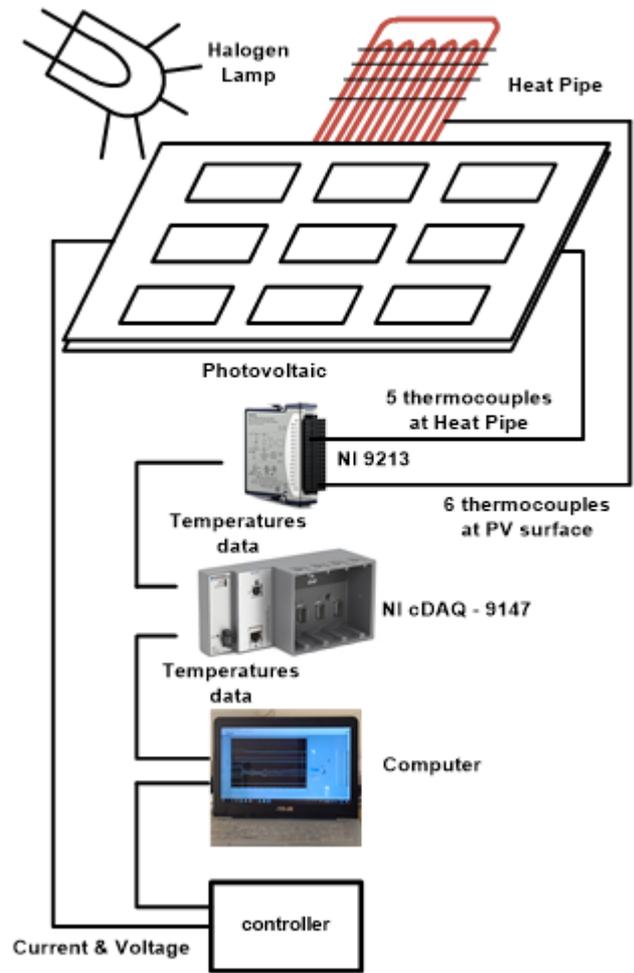


Fig 2. Experiment setup

III. RESULT AND DISCUSSION

A. Measurement Result

The measurement of front-left, front-center, front-right, back-left, back-center and back-right temperatures of solar panel (PV) without heat pipe is carried out with irradiation using a halogen lamp of 1000 W and the distance of 50 cm for 21600 seconds. The data of ambient temperature is also collected. Figure 3 shows the measurement result.

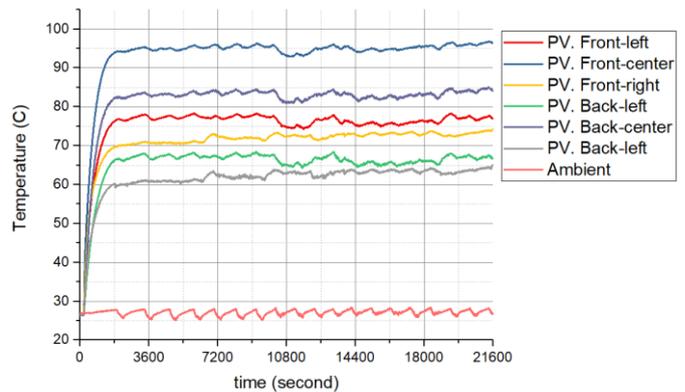


Fig 3. Solar panel temperature without heat pipe

Temperature measurement of front-left, front-center, front-right, back-left, back-center and back-right of solar panel (PV) with heat pipe is also carried out with irradiation using an equal halogen lamp of 1000 W and the distance of 50 cm for 21600 seconds. The data of ambient temperature is also collected and shown in Fig. 4.

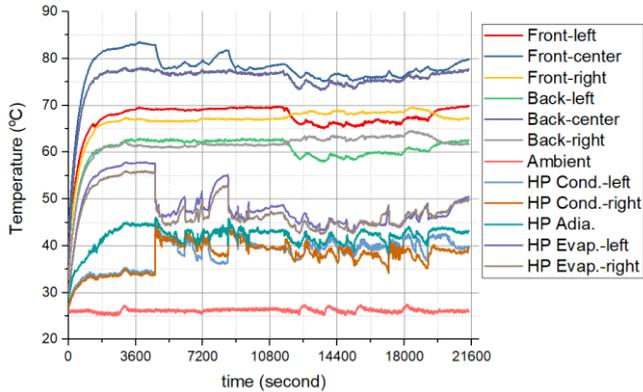


Fig 4. Solar panel temperature with heat pipe

B. Thermal Management Using Heat Pipe

Heat pipes consist of parts namely evaporator, adiabatic and condenser. The evaporator is the part where the heat is absorbed, and the working fluid is evaporated. Condenser is the part where the vapor of working fluid undergoes condensation and the heat is released. Adiabatic is the connecting part between the evaporator and condenser. In this study, the heat from solar panel is absorbed by evaporator which is equipped with a metal plate. Figure 5 shows the graph of average surface temperature with and without heat pipe irradiated with a halogen lamp of 1000 W and the distance of 50 cm for 21600 seconds. Average 2 draws the average surface temperature without heat pipe of 74.58 °C. It has maximum and minimum average surface temperatures of 77.08 °C and 74.66 °C, respectively. Meanwhile Average 1 draws the average surface temperature with heat pipe of 68.25 °C. It has maximum and average surface temperatures of 70.31 °C and 67.04 °C, respectively. Therefore, installation of heat pipe at back-center of 30 Wp solar panel manages a lower surface temperature of 6.33 °C in average.

Heat transfer occurs in the heat pipe as indicated by changes in temperature at left condenser (HP Cond.-left) and right condenser (HP Cond.-right) with left evaporator (HP Evap.-left) and right condenser (HP Evap.-right) pairs. Temperature of adiabatic (HP-Adia.) also shows heat transfer between evaporator and condenser. The peaks of evaporators temperature occur at 4638th, 6227th, 7113th, 8547th, 9087th, 9659th seconds and it occurs again at 17166th, 18619th, 19248th seconds. In the same moment, the valleys of condenser temperature occur. This phenomenon shows the thermal management of 30 Wp solar panel using heat pipe as seen in Fig. 5.

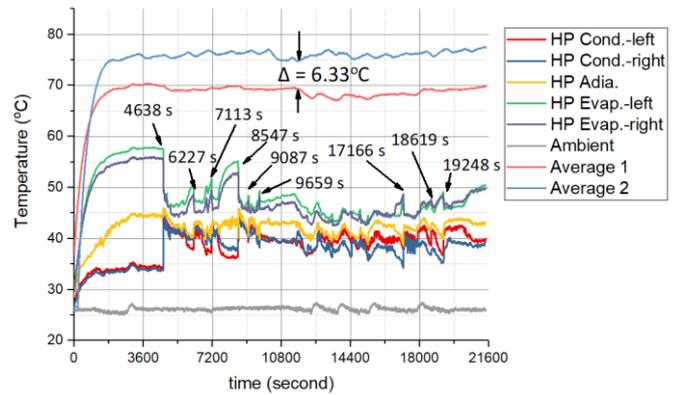


Fig 5. Thermal management of 30 Wp solar panel using heat pipe

IV. CONCLUSION

In this experiment, a copper-based heat pipe with methanol working fluid as thermal management. It is applied on 30 Wp solar panel is irradiated by 1000 W halogen lamp indoor at distance of 50 cm. Heat pipe with a heat absorption area of 60 cm² can reduce the average surface temperature by 6.33 °C for solar panel with an area of 3500 cm². This happens because of the heat transfer from evaporator to condenser, and vice versa. The heat pipe can effectively transfer the heat and lower the solar panel surface temperature. It shows the ability of heat pipe as thermal management on solar panel.

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 also would like to thank to Dr. Wayan Nata Septiadi, Dr. Adi Winarta, Mr. Wayan Sukayasa and Mr. Wayan Dharma Wirahadi for your kind support.

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