Characteristic comparison of photovoltaic module and photovoltaic thermal

Krismadinata^{1,3,}, Remon Lapisa², Syahril² and Asnil³*

¹Energy Research Centre, Faculty of Engineering, Universitas Negeri Padang, 25171 Padang, Indonesia

²Depart. of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Padang, 25171 Padang Indonesia

³Depart.of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang, 25171 Padang, Indonesia

Abstract. This paper discusses an attempt to compares the electrical characteristics of two solar modules of the same type and size in which one of the solar modules at the bottom is mounted a copper pipe for circulating water (as call photovoltaic thermal). The research was steered to observe water cooling effect to electrical characteristics of PV module. This system serves as a heat absorption on the bottom of the solar module. The experiment is conducted at the same time, place, and sunlight intensity conditions for both solar modules. The characteristics of short-circuit current, open circuit voltage, upper and lower temperature and the irradiation of sunlight from the two solar modules are observed. The test results show that photovoltaic thermal generate greater electrical power than solar modules not equipped with heat absorption

1 Introduction

Recently, one of the big problems facing the world is global warming. The massive use of fossil fuels for industry and transportation has triggered a large amount of CO₂ content in the air that has an impact on the greenhouse effect. The use of energy sources that are not derived from fossils is one alternative to overcome global warming. Solar energy will not be exhausted until the doomsday. This is one alternative solution in the use of energy. Popular technologies in utilizing solar energy are solar heaters and solar modules (photovoltaic).

Solar heater is a technology that utilizes the sun beam into heat energy. This technology is widely used in household to heat water. The solar module also known as photovoltaic (PV), can convert sunlight into electrical energy. This technology is widely used for the electrification of villages in remote area where they are away from the electricity connection utilities.

* Corresponding author: krisma@ft.unp.ac.id

The problem of PV is during operation only about 15% of the solar radiation can be converted into electrical energy and others are wasted into heat. Though solar energy contains sun radiation and heat. It is very unfortunate if the energy used is just one of the two elements. One of PV weakness is the power efficiency of the PV decrease as the temperature around the PV module increases [1].

This is a reason, why the concept of "PV cooling" becomes so important in PV generation. It is applied to increase the electrical power generated. The PV cooling reduces the heat around the PV module and at the same time, it is gotten heat energy source. The technology that can answer the above problem is by combining a PV module with a solar water heating module. This method is employed to improve the characteristics of solar panels by draining water under solar panels. They absorb heat around the solar panel. This system is known as PV solar heater or Photovoltaic Thermal (PVT). This system can eliminate external power source for water heater as well as to cool the solar PV module.

PVT technology has been realized since 1950 [2] and developed by [3]. This technology is long over reviewed. In the 2000s, it was continued to review by [4-8]. The optimizing of PVT design has been conducted by [9]. Research on the Rhodes Island has been reported that PVT efficiency was 9% lower than conventional solar heaters [10]. The research on PVT technology is also quite popular in Indonesia, especially employing water as heat absorbing media. [11-13].

In this paper, an effort to comprise the electrical characteristics of PV module and PVT module. The research was conducted to inspect water cooling effect to electrical characteristics of PV module.

2 Methods

The experiment was conducted employing two PV modules of the same size, power, and model. One PV module is equipped with copper pipes, water pumps that can drain the water so it can function to absorb heat. When the temperature inside the copper pipe is larger than 420C the water pump works to drain the hot water to the storage tank and draw cold water back into the copper pipe.

The PVT is designed employing copper pipes as ducts that are placed under the solar panels. They are designed spiral-shaped. The diameter of ducts is 5/8 inch. This spiral copper pipe is placed under a solar module with a cross-sectional position along the side of the solar module. Those ducts is built with 10 curvatures. They are designed to flow more fluids. The experiment setup can be shown in Figure 1.

Fig. 1. Design of experiment setup

The experiments were conducted at Faculty of Engineering Universitas Negeri Padang (FT UNP). The latitude of FT UNP, Padang City West Sumatera is -0.9470832 or 0°56'49.5"S, and the longitude is 100.4172 or 100°25'1.85"E. The characteristics explored are solar irradiation, temperature of PV module on the upper side, temperature PV module on the bottom side, open-circuit voltage, and short-circuit current from PV module. Observations were also conducted at the same time as the same measuring instrument. Both solar modules used have specifications as shown in table 1.

Table 1. Specification of PV module used

Specification	Rate
Pmax	50Watt (Peak)
Voc	21.6 Volt
Isc	2.98 Ampere
Vmp	17.6 Volt
Imp	2.85 Ampere
Size (mm)	835 X 540 X 28

3 Results and Analysis

A copper pipe that serves as a water flow conduit placed on the bottom side of the solar module can be seen in Figure 2. The conduit configuration is designed circles. This is done to get the amount of heat absorbed more.

A complete series of PV module and PVT module testing can be shown in Figure 3. The experiments setup is equipped with a monitoring system. It records all data regarding to PV and PVT modules characteristic. All measured data are stored in the memory of computer and processed and displayed in the graph. The observed data are irradiation of sunlight, ambient temperature, maximum output power, open-circuit voltage (V_{OC}) and short circuit-current (I_{SC}).

The data are collected starting morning at 9 o'clock and end at 15 o'clock. The monitoring system updates the data every 15 minutes. It needs to get detail information on characteristics changes. In Figure 4 the temperature chart changes to both solar modules.

The observed temperature is the temperature above the solar module. The maximal temperature achieved in this observation reaches 58⁰C in the PV module, while temperature on upper side of the PVT module is lower than the PV module.

Figure 5 shows that the temperature on bottom side of the PVT module is lower than the PV module. The maximum temperature the PVT module reaches is 44⁰C, corresponding to the initial temperature reference.

Fig. 2. Copper pipe as water flow conduit

Fig. 3. Experiment test setup

Fig. 4. Temperatures on upper side

Fig. 5. Temperatures on bottom side

The voltage and current generated by the PVT module are higher than the PV module. It is especially at 13:00, the open-circuit voltage and short-circuit current of the PV module become the lowest at that time. this is shown in Figure 6 and Figure 7.

The high voltage and current on the PVT module compared to the PV module also impact on the power generated. This is shown in Figure 8.

Fig. 6. V_{OC} of PV and PVT modules

Fig. 7. I_{SC} of PV dan PVT modules

Fig. 8. Power comparison PV and PVT

Fig. 9. Solar irradiance at experiment test

The highest solar irradiance is achieved at 13:00, as well as the current generated by the PVT module. At 11:15, the irradiation of light is quite high also close to irradiation at 13.00, but within the time it occurs clouds that reduce irradiation received solar module. This is illustrated in Figure 9.

4 Conclusions

In this paper, the performance of the PV module and PVT module is investigated. Data of temperature around the PV and PVT module, solar irradiation, short circuit current, open circuit voltage of the PV modules are explored. Those data are processed and analyzed for both solar modules. The results show that the PVT module has a better performance in terms of the power generated than the PV module. The liquid or water that passes on the PVT module acts as a coolant or heat absorber from the PV module so that it reduces the temperature of the solar module. The dropping temperature of the solar module can increase the electrical power generated by the module.

Authors gratefully acknowledge the support of Ministry of Research, Technology and Higher Education Republic of Indonesia (KEMENRISTEKDIKT) for providing financial support under scheme research through PUPT grant No. 855/UN35.2/PG/2018.

References

1. H. G. Teo, P. S. Lee, & M. N. A. Hawlader , *Applied Energy*, **90** 309-315 (2012)
2. H. C. Hottel, A. Whillier, (1958)
3. L. W. Florschuetz. *Solar Energy*, **22** 361–366 (1979)
4. H. A. Zondag, D. W. de Vries, W. G. J. van Helden, R. J. C. van Zolingen, A. A. van Steenhoven, *Solar Energy* ,113–128 (2002)
5. A. Tiwari, M. S. Sodha, *Solar Energy*, **80** 751–9 (2006)
6. T. T. Chow, *Applied energy*, **87** 365-379 (2010)
7. Y. Tripanagnostopoulos, T. H. Nousia, M. Souliotis & P. Yianoulis, *Solar energy*, **72** 217-234 (2002)
8. P. G. Charalambous, G. G. Maidment, S. A. Kalogirou, & K. Yiakoumetti, *Applied Thermal Engineering*, **27** 275-286 (2007)
9. G. Mittelman, A. Kribus & A. Dayan, *Energy Conversion and Management* **48** 2481-2490 (2007)
10. N. Christandonis, G. A. Vokas & F. Skittides, *WSEAS Transactions on Circuits and Systems* 3 (2004)
11. M. P. Lukman, & J. Junaedy, *Stmik Kharisma Makassar* **2** 34-45 (2017)
12. Mustafa, R. Magga, & Y. Arifin, *Jurnal IPTEK* **19** 67-74 (2015)
13. R. Subarkah & Belyamin, *Poli-Teknologi*, **10** (2013)