Comparison of solar panel cooling system by using dc brushless fan and dc water

Y.M.Irwan[1,a], W.Z.Leow[1,b], M.Irwanto[1], Fareq.M[1], S.I.S,Hassan[1], I.Safwati[2] and A.R.Amelia[1]

[1] Centre of Excellence for Renewable Energy, School of Electrical System Engineering, University Malaysia Perlis, (UniMAP), Malaysia.

[2]Institute of Engineering Mathematics, University Malaysia Perlis, (UniMAP), Malaysia.

E-mail: [a]irwanyusoff@unimap.edu.my, [b]wzjohnnyleow_90@hotmail.com

Abstract. The purpose of this article is to discuss comparison of solar panel cooling system by using DC brushless fan and DC water pump. Solar photovoltaic (PV) power generation is an interesting technique to reduce non-renewable energy consumption and as a renewable energy. The temperature of PV modules increases when it absorbs solar radiation, causing a decrease in efficiency. A solar cooling system is design, construct and experimentally researched within this work. To make an effort to cool the PV module, Direct Current (DC) brushless fan and DC water pump with inlet/outlet manifold are designed for constant air movement and water flow circulation at the back side and front side of PV module representatively. Temperature sensors were installed on the PV module to detect temperature of PV. PIC microcontroller was used to control the DC brushless fan and water pump for switch ON or OFF depend on the temperature of PV module automatically. The performance with and without cooling system are shown in this experiment. The PV module with DC water pump cooling system increase 3.52 %, 36.27 %, 38.98 % in term of output voltage, output current, output power respectively. It decrease 6.36 ˚C compare than to PV module without DC water pump cooling system. While DC brushless fan cooling system increase 3.47 %, 29.55 %, 32.23 % in term of output voltage, output current, and output power respectively. It decrease 6.1 ˚C compare than to PV module without DC brushless fan cooling system. The efficiency of PV module with cooling system was increasing compared to PV module without cooling system; this is because the ambient temperature dropped significantly. The higher efficiency of PV cell, the payback period of the system can be shorted and the lifespan of PV module can also be longer.

1. Introduction

With worldwide, energy represents an essential part within human modern society. The energy will be separating in two kinds that are non-renewable energy and renewable energy. Just as the effect of planet global economic development and also growing requirement regarding energy, the non-renewable energy (coal, oil and also natural gas) will be quickly raising. Other than that, the consumption of non-renewable energy raise and lead to the level of atmospheric carbon dioxide to increase that result in temperature of planet to increase. Renewable energy often known as non-conventional energy just likes tidal wave energy, solar energy, geothermal energy, hydropower, and so on. Once the non-conventional energy demand can be first individual make use of its decision, the conventional energy demand will likely be reduce. The actual offered involving green energy to produce an alternative in order to resolve the situation involving worldwide warming.

PV energy is a renewable energy which it is can be a process which will be made of sun ray. Cellular of PV makes use of semi-conducting products, to make certain in case the sunlight hit, which is often became electrical power. Solar cells are made regarding various layers associated with thin silicon. PV is usually desirable electrical energy; it can be abundant, hushed in addition to environmentally friendly, and it can certainly apply in numerous applications. In general, three major sorts of technology are utilized from the manufacturing of photovoltaic cells: monocrystalline; polycrystalline; and also amorphous silicon [1]. PV technology is usually any one of a very useful solution for renewable energy, seeing that it could be natural resources and also pollute-free. Moreover PV technology can certainly to decrease varieties of greenhouse gas emission. The PV cell necessary substance is actually silicon semiconductor (Si).

The specific ambient temperatures and also sun irradiance participate in significant aspect intended for productivity of the PV module. When the ambient temperature of PV module is usually raise, the actual efficiency of PV module is decrease and vice versa. Whenever sun irradiance is usually increased, the output power of PV furthermore increases. More efficiency of PV module, investment payback period of the system can certainly shorten as well the lifespan of PV module will also be extended. This standard rule is certainly the decline through the open cell voltage and also short circuit current drop is determined. Consequently, an efficient PV performance circumstance required cooling. Although PV module operating outside; PV modules have a high irradiance condition upon attaining high temperatures.

J.K. Tonui, [2] researches the improvement of the low cost air typed PV/T collector with the problem of less material consumption and low running costs. Using the ways of add thin flat metal plate in the centre or just add fins in the flow channel, It will achieve high heat energy output, and decrease the temperature of PV, in order to improve the efficiency of electric. J. K. Tonui [2] described air cooling is preferred than the other cooling arrangements due to minimal use of material and low operating cost despite its poor thermo physical properties. Kozak et al. [3] discussed a study of temperature variation of the water cooled PV solar template where the system included the heat exchanger mathematical module has been established and the variation of template temperature with the amount of cooling water has been calculated and analyzed under the different power and the inlet water temperature. In solar PV water-cooling type template system, temperature of PV wall reduced with increasing the cooling water flow, but reduced the amount minimized [3].

Arab, A. [4] reported the water spraying is atomized by control system and spraying unit. The control system includes temperature sensor and microcontroller circuit. Odeh S. [5] carried out the heat energy generated by the modules due to high temperature sunlight will be absorbed by the water particles, allowing the temperature of the module not to rise very high. Gang et al. [6] experimentally studied the performance of a novel heat pipe photovoltaic/ thermal system and validated the model output with measured data. The experimental results showed an improvement in the system efficiency with cooling with water circulation. Recently, Tina et al. [7] investigated the effect of submerging a photovoltaic system in water on the efficiency of the system under high irradiance and ambient temperature conditions.

Moharram et al. [8] developed a cooling system based on water spraying of PV panels. A mathematical model has been used to determine when to start cooling of the PV panels as the temperature of the panels reaches the maximum allowable temperature (MAT). Dan M. J. Doble [9] mentioned when comparing the efficiency reduction of the module operating at high temperature and the module with water layer reducing the solar irradiation towards the module, the performance of the module with the water layer on surface top has better efficiency improvement, thus the effects of refraction on sunlight due to existence of water is negligible, as the efficiency decrease due to this reason is relatively small. Chinamhora et al [10] used a water cooling system on the front and back of the PV module and the found that the cooling system could improve the efficiency of PV module during clear days, while it had disadvantages during cloudy days. Asachi [11] presents a combined photovoltaic and thermal Solar Panels in order to reduce the heat produced by PV system and enhance the output energy of PV and thermal collector.

Sharp Solar Module ND-130T1J has been chosen to analysis PV modules performance in this investigation. The primary concentration is compared with parameter performances of the PV module with and without cooling system. A report consists of the key parameters and the provisional result through the component to the user.

2. Methodology

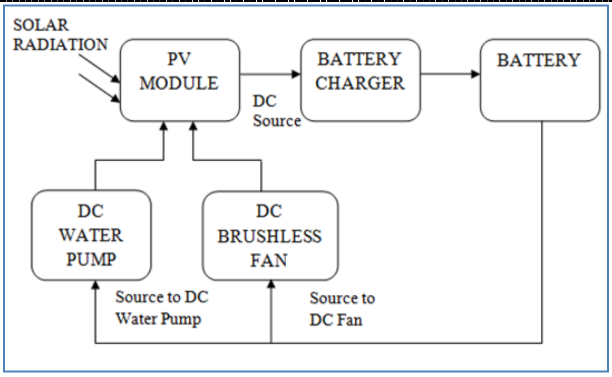

Figure1. Block diagram overview of the investigation.

Figure 1 displays the block diagram summary of the investigation. As a way to satisfy the requirement of investigation, the solar energy is chosen as a main supply of this design. The PV module produces electrical energy and provides DC supply to battery charger. The output power of PV module is used to charge the 12 V_{DC} batteries by using battery chargers. It continually charges the battery until it shows at the sign of complete condition on which will cut-off charging process. The utilization of battery is used to store electrical energy that generate by PV module. Battery provide DC source to DC cooling system that is places at back side (DC brushless fan) or front side (DC water pump) of PV module. DC cooling system to reduces temperature for improving efficiency output power of PV module. Two various methods of DC cooling systems have been constructed that is DC brushless fan cooling system and DC water pump cooling system.

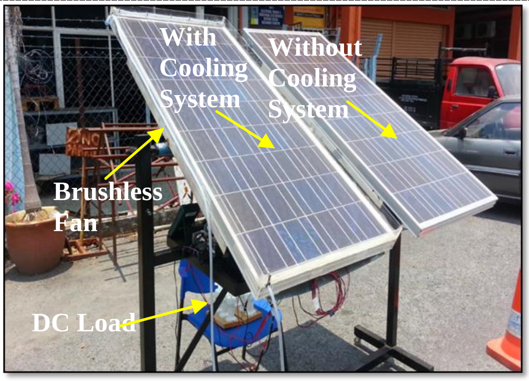

Figure 2. DC brushless fan cooling system.

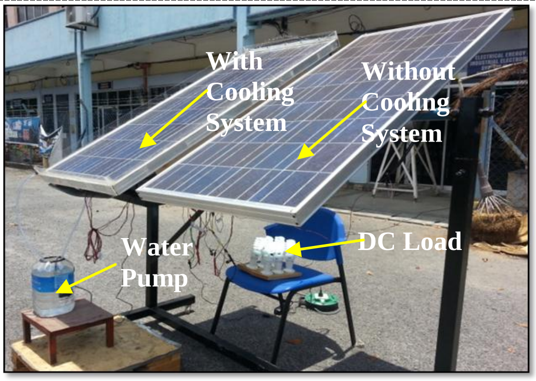

Figure 3. DC water pump cooling system.

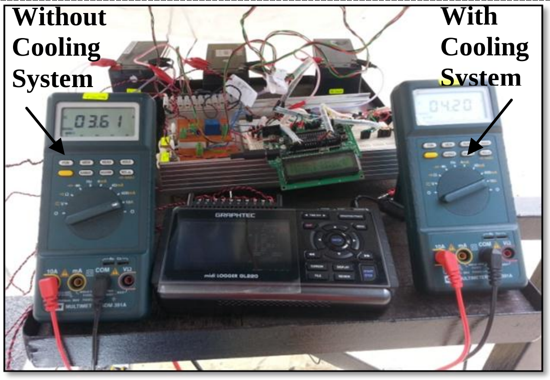

Figure 4. Setup experiment with measurement devices.

Within this investigation, two Sharp Solar Module ND-130TIJ polycrystalline solar modules were utilized to convert solar energy into electrical energy. A Sharp Solar Module ND-130T1J was used with 130 W peak power, 22.0V $V_{oc,}$ 8.09A $I_{sc,}$ module efficiency is 13 % under STC. A PV module set up DC brushless fan cooling system whiles another PV module without DC brushless fan cooling system. Both PV modules were constructed connected with DC lamps (84 W).

Besides that, the DC cooling system is controlled by control system which is microcontroller circuit and temperature sensor. LM 35 as temperature sensor is placed on the back side of the PV module. Four temperatures sensors installed at every PV module which a couple of temperature sensors at the top side along with another a couple of temperature sensors at the top bottom of PV module. The data of temperature ranges were assessed and recorded by using Midi Logger GL220 in most ten moments. Function involving PIC 18F4550 microcontroller is to switch ON / OFF the DC cooling method automatically. When the temperature of PV module reach at or more than 35 ˚C that detected by using LM 35, the PIC 18F4550 is switched ON the DC cooling system and the other way around. After switch on the cooling system, the brushless fans were blowing at the backside or water pump was spray water at front side of PV module to cool down the temperatures of PV module. This controller system is an intelligent system because it will run the cooling system automatically when the temperature of PV module reaches setting level that detected by temperature sensors and avoid waste electrical energy.

Midi Logger GL220 was using to measure and collect output voltage of both PV modules. In each ten minutes, the output current of both PV modules were measured and recorded by using Digital Multimeter. The daily ambient temperature and solar irradiance were determined by using Davis Vantage PRO2 Weather.

3. Results and discussion

3.1 The Result of DC Brushless Fan Cooling System

Two various methods of cooling system were conducted at Centre of Excellence Renewable Energy (CERE) on 31 March 2014 from 9:00 a.m until 5:00 p.m. The DC cooling systems were testing at the outdoor CERE.

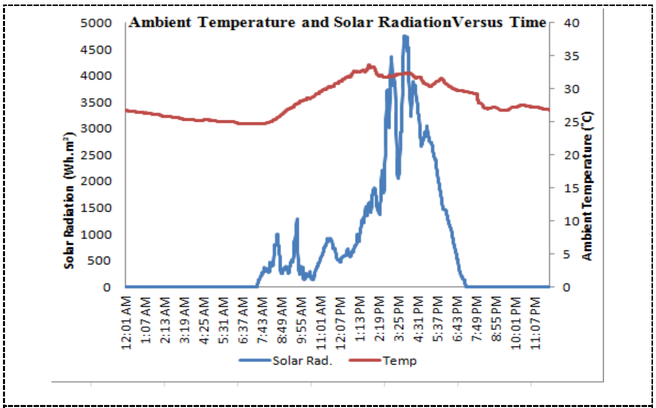

Figure 5. Solar radiation and ambient temperature on 31 March 2014 for testing DC cooling system.

Figure 5 displays solar radiation and ambient temperature on 31 March 2014. The maximum solar radiation occurs at 15:48 p.m which was 4752 Wh/m ^{2} and the maximum ambient temperature was 33.6 ˚C which occur at 13:47 p.m.

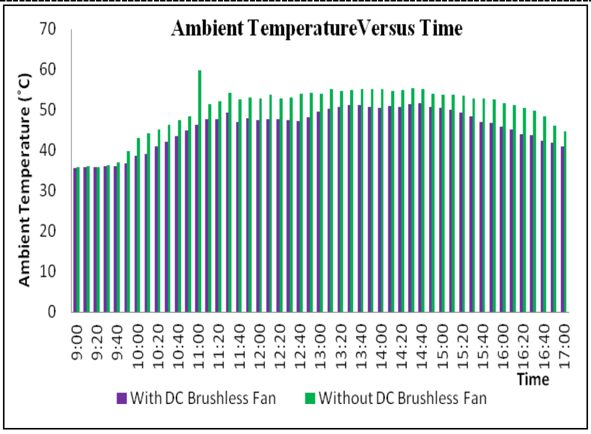

Figure 6. Ambient temperature versus time for PV module with and without DC brushless fan.

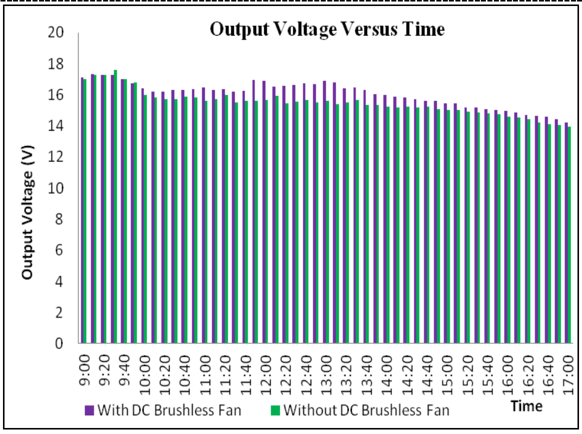

Figure 7. Output voltage versus time for PV module with and without DC brushless fan.

Figure 6 displays ambient temperature versus time for PV module with brushless fan cooling system and PV module without brushless fan cooling system. The average temperature of PV module along with cooling system can be 44.77 ˚C while the average temperature of PV without cooling system seems to be 50.87 ˚C. The temperature variant of PV module without cooling system seemed to be raising 6.1 ˚C reviews to be able PV module with cooling system. Efficiency of PV module can certainly be affected by ambient temperature.

Figure 7 shows output voltage versus time for PV module with and without DC brushless fan. The figure displays the maximum output voltage of PV module with DC brushless fan cooling system was

17.31 V while minimum output voltage was 14.21 V. The average output voltage of PV module with DC brushless fan cooling system was 16.05 V. In the same time, the maximum output voltage of PV module without DC brushless fan cooling system was 17.61 V while minimum output voltage was 13.93 V. The average of output voltage which produced by PV module without DC brushless fan cooling system has been 15.49 V. Solar radiation was in fragile condition and some of solar cells cannot be found worked well that afflicted the productivity voltage reduction in this situation. Compared between these kinds of the two systems, the output voltage increased 3.47 % whenever using cooling system. This kind of is caused by the ambient temperature of PV module surface with cooling system decrease; the output voltage of PV module with cooling system has been increasing.

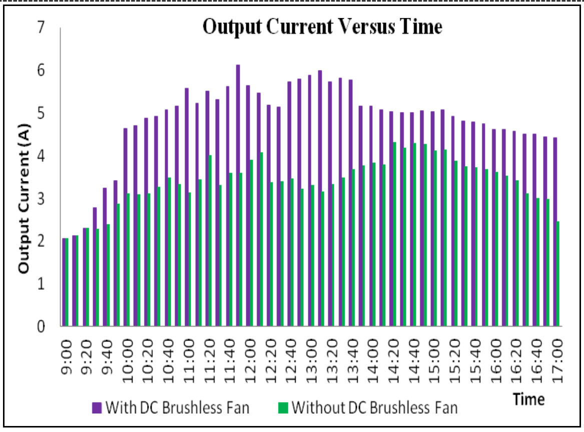

Figure 8. Output current versus time for PV module with and without DC brushless fan.

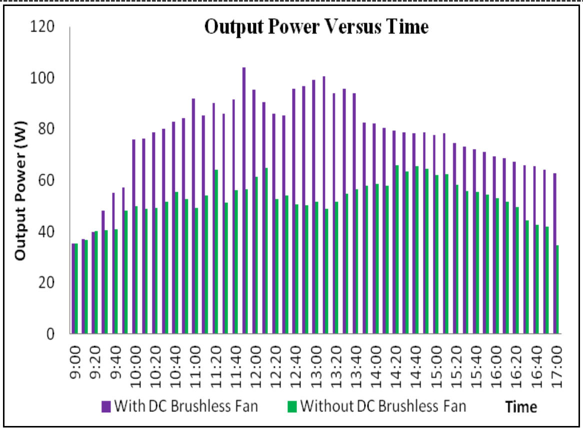

Figure 9. Output power versus time for PV module with and without DC brushless fan.

Figure 8 displays examine concerning output current for PV module with cooling and without cooling situation. It could be discovered maximum output current that is generated by PV module with cooling system was 6.13 A while the minimum output current seemed to be 2.07 A. The average output current seemed to be 4.84 A. In the same time, the absolute maximum output current of PV module without cooling system achieved seemed to be 4.32 A while the minimum output current shown on 2.08 A. 3.41 A seem to be the average output current of PV module without cooling system. Through in comparison concerning these kinds of each system, the output current improved 29.55 % when using cooling system. From the end result, it could be discovered that whenever temperature along with solar irradiance increase, the output current likewise increased. Consequently, the output current increased with major percentage in comparison to output current when using DC brushless fan cooling system.

Figure 9 shows output power for PV module with DC brushless fan cooling system and PV module without DC brushless fan cooling system. That figure displays PV module with DC brushless fan cooling system, the output power ended up being a bit improved through 9:00 a.m as well as attained with maximum level at 11:50 p.m after which lowered until finally 5:00 p.m. The adjusting regarding solar irradiance as well as ambient temperature which effect on if which output power unable to keep firm. This condition happen due to the impression regarding winds and clouds the act as barriers within reflected the intensity of light. The maximum output power of PV with DC brushless fan cooling system was measured and calculated at 104.09 W while the minimum output power was 35.44 W. The average output power of PV module with DC brushless fan cooling system was 77.63 W.

In the other sides, the output power of PV module without cooling system was below than 70.0 W. That Figure 9 shows that it can be determined output power starting move increased and reached maximum output power at 65.92 W which is at 14:20 p.m then moved decrease until 5:00 p.m. While

Journal of Physics: Conference Series **622** (2015) 012001 doi:10.1088/1742-6596/622/1/012001

the minimum output power of PV module without DC brushless fan cooling system was 34.41 W. and the average output power of PV module without DC brushless fan cooling system was 52.61 W. Through in comparison concerning these kinds of each system, the output power improved 32.23 % when using DC brushless fan cooling system.

3.2 The Result of DC Water Pump Cooling System

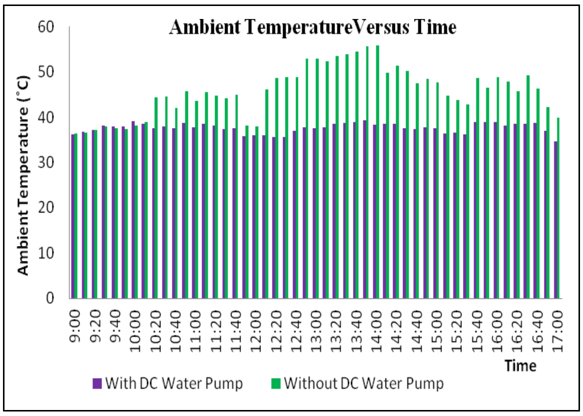

Figure 10. Ambient temperature versus time for PV module with and without DC water pump cooling system.

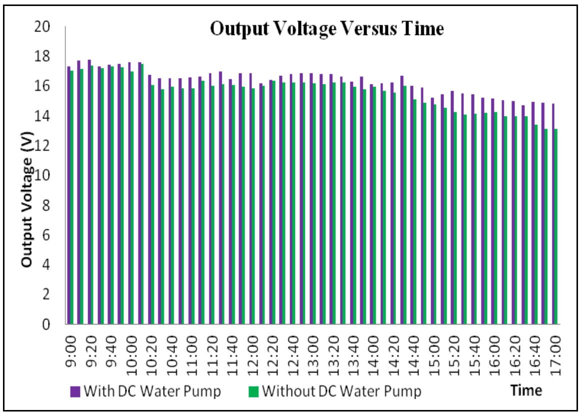

Figure 11. Output voltage versus time for PV module with and without DC water pump cooling system.

Figure 10 demonstrates ambient temperature versus time under PV module with water pump cooling system and PV module without water pump cooling system. The average temperature of PV module with cooling system is 37.65 ˚C while the average temperature of PV without cooling system was 45.74 ˚C. The temperature variation of PV module without cooling system was increase 6.36 ˚C compare to PV module with cooling system. Performance of PV module can be affected by ambient temperature. Figure 11 displays the average output voltage of PV module with DC water pump cooling system was 16.453 V while the average of output voltage that produced by PV module without DC water pump cooling system was 15.87 V. Compared between these both systems, the output voltage increased 3.52 % when using cooling system.

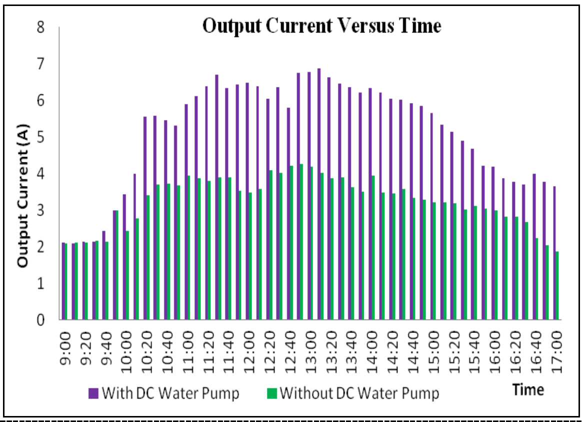

Figure 12. Output current versus time for PV module with and without DC water pump cooling system.

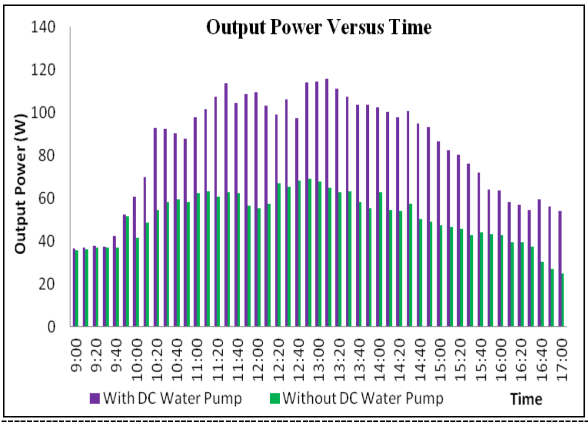

Figure 13. Output power of DC water pump under cooling and without DC water pump cooling system.

Figure 12 shows the average output current that produced by PV module with DC water pump cooling system was 5.13 A while 3.27 A was the average output current of PV module without DC water pump cooling system. By compared between these both systems, the output current increased 36.27 % when using DC water pump cooling system.

Figure 13 displays output power for PV module with DC water pump cooling system and PV module without cooling system. The average output power of PV module with cooling system seemed to be 83.79 W whereas the average output power of PV module without cooling system seemed to be 51.13 W. The increase percentage in the output power in unit of electricity is calculated to be 38.98 %.

3.3 The Result of the Result of Comparison of Solar Panel Cooling System by Using DC Brushless Fan and DC Water Pump

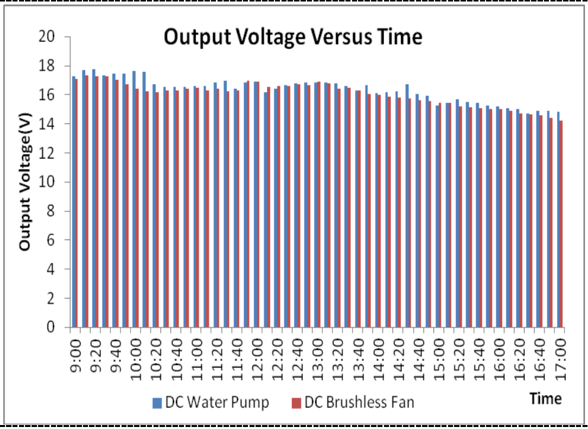

Figure 14. Comparison between DC brushless fan and DC water pump in term of output voltage.

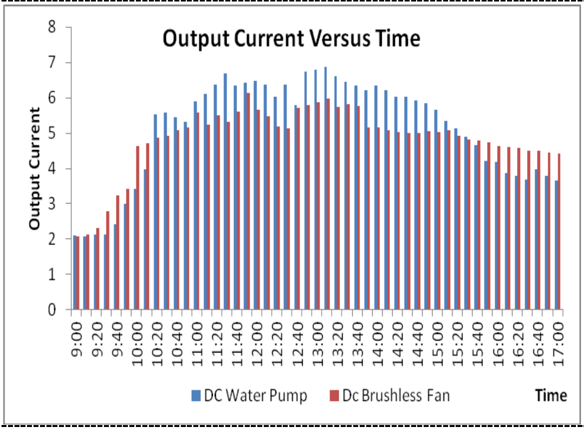

Figure 15. Comparison between DC brushless fan and DC water pump in term of output current

Figure 14 presents comparison of output voltage between DC brushless fan and DC water pump. The average output voltage of PV module with DC brushless fan cooling system was 16.05 V while the average output voltage of PV module with DC water pump cooling system was 16.45 V. The output voltage of PV module with DC brushless fan cooling system increase 3.47 % compared to PV module without DC brushless fan cooling system. While output voltage of PV module with DC water pump cooling system increase 3.52 % compare to PV module without DC water pump cooling system. PV module with DC water pump cooling system will generate more 0. 05 % output voltage compared to PV module with DC brushless fan cooling system.

Figure 15 demonstrates comparison of output current between DC brushless fan and DC water pump. The average output current of PV module with DC brushless fan cooling system was 4.84 A while the average output current of PV module with DC water pump cooling system was 3.27 A. The output current of PV module with DC brushless fan cooling system increase 29.55 % compared to PV module without DC brushless fan cooling system. While output current of PV module with DC water pump cooling system increase 36.27 % compare to PV module without DC water pump cooling system. PV module with DC water pump cooling system will generate more 6.72 % output current compared to PV module with DC brushless fan cooling system.

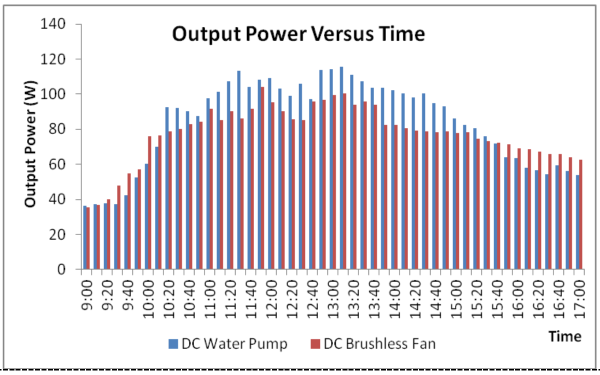

Figure 16. Comparison between DC brushless fan and DC water pump in term of output power.

Figure 16 illustrates comparison of output power between DC brushless fan and DC water pump. The average output power of PV module with DC brushless fan cooling system was 77.63 W while the average output power of PV module with DC water pump cooling system was 51.13 W. The output power of PV module with DC brushless fan cooling system increase 32.23 % compared to PV module without DC brushless fan cooling system. While output power of PV module with DC water pump cooling system increase 38.98% compare to PV module without DC water pump cooling system. PV module with DC water pump cooling system will generate more 6.75 % output power compared to PV module with DC brushless fan cooling system.

Table 1. Percentage in compare between with cooling system and without cooling system in term of ambient temperature, output voltage, output current and output power.

Method / Parameters	Brushless Fan	Water Pump
Ambient Temperature	6.1 °C	6.36 °C
Output Voltage	3.47 %	3.52 %
Output Current	29.55 %	36.27 %
Output Power	32.23 %	38.98 %

4. Conclusion

This paper has presented various type of DC cooling system with this PV module cooling system. PIC 18F4550 microcontroller to control the particular cooling system that will diagnose by LM 35 either switches ON or perhaps switches OFF cooling system automatically. Solar irradiance and ambient temperature could be the have effect on the efficiency of PV module. Any time temperature increase, output current is going to be increase but output voltage and power will probably reduce and the other way around. When the solar irradiance increase, output current and power will increase with linear and output voltage will increase with marginal and vice versa. With compare between both systems of various types DC cooling system, the PV module with DC water pump cooling system is most efficient compare to DC brushless fan cooling system. The PV module with DC water pump cooling system increase 3.52 %, 36.27 %, 38.98 % in term of output voltage, output current and output power. It decrease 6.36 ˚C compare than to PV module without DC water pump cooling system. The

DC brushless fan cooling system increase 3.47 %, 29.55 %, 32.23 % in term of output voltage, output current and output power. It decrease 6.1 ˚C compare than to PV module without DC brushless fan cooling system. The efficiency of PV module with cooling system was be improving as compared to PV module without cooling system, the reason being that the ambient temperature decreased considerably. More efficiency associated with PV module, investment payback period of the system can minimize and also the lifespan associated with PV module can also be prolonged.

5. Acknowledgment

The authors gratefully acknowledge to Kementerian Pengajian Tinggi Malaysia supported under Knowledge Transfer Program (KTP) and the contributions and cooperation from member Centre of Excellence for Renewable Energy (CERE), University Malaysia Perlis (UniMAP) for their work on the original version of this document.

6. References

[1] AC Moreira Soares, *et al.* "Simulation of a photovoltaic model using bisection method". 2011, pp. 807-811.

[2] J.K. Tonui, Y. Tripanagnostopoulos Air-cooled PV/T solar collectors with low cost performance improvements. *Solar Energy*, 2007, pp.498–511.

[3] T. Kozak, W. Maranda, A. Napieralski, "Influence of Ambient Temperature on the Amount of Electric Energy Produced by Solar Modules." MIXDES 2009, *16th International Conference Mixed Design of Integrated Circuits and Systems*, June 25-27, 2009.

[4] Arab, A., F. Chenlo and M. Benghanem, Loss-of-load probability of photovoltaic water pumping systems. *Solar Energy,* 76,2004: 713-23.

[5] Odeh. S., Behnia. M., Improving Photovoltaic Module Efficiency using Water Cooling, *Taylor and Francis Ltd, Heat Transfer Engineering*, Volume 30, 2009, pp. 499 – 505.

[6] Gang P, Huide F, Huijuan Z, Jie J. Performance study and parametric analysis of a novel heat pipe PV/T system. *Energy* 2012;37(1):384e95.

[7] Tina GM, Rosa-Clot M, Rosa-Clot P, Scandura PF. Optical and thermal behavior of submerged photovoltaic solar panel: SP2. *Energy* 2012;39(1):17e26.

[8] K.A. Moharram, M.S. Abd-Elhady, H.A. Kandil, H. El-Sherif, Enhancing the per-formance of photovoltaic panels by water cooling, *Ain Shams Engineering Journal 4* (4) (2013) 869–877.

[9] El-Shobokshy M. S., H. F. Effect of dust with different physical properties on the performance of photovoltaic cells. *Solar Energy* 51, 2008, pp. 505-511.

[10] H.G. Doble. D. M. J., Minimization of Reflected Light in Photovoltaic Module, *Renewable Energy World,* Article 03, 2013.

[11] T. Chinamhora, G. Cheng, Y. Tham and W. Irshad: PV Panel Cooling System for Malaysian Climate Conditions, International Conference on Energy and Sustainability, April 27, 2013, Karachi, Pakistan.

[12] Gheorghe Asachi: Combined Photovoltaic and Thermal Solar Panels -Enhanced Energy Conversion and Heat Transfer, *Termotehnica* (2013):135-140.

[13] H.G.Teo, P.S. Lee, M.N.A. Hawlader, "An Active Cooling System for PV Modules," *Applied Energy*, Vol.90, pp. 309-315, 2012.

[14]T. H. Guan, "PV Thermal (PV/T) System: Effect of Active Cooling," Thesis (B. Sc Eng (NCKU)), National University of Singapore, Singapore, 2010.

[15] Brinkworth, B. J., Cross, B. M., Marshall, R. H., and Yang, H., 1997, "Thermal Regulation of Photovoltaic Cladding," *Sol. Energy*, 61, pp. 169–178.