Journal of Scientific Research & Reports
3(21): 2801-2816, 2014; Article no. JSRR.2014.21.008
ISSN: 2320–0227

SCIENCEDOMAIN ***international***
www.sciencedomain.org

PIC 18F4550 Controlled Solar Panel Cooling System Using DC Hybrid

W. Z. Leow[1*], Y. M. Irwan[1], M. Irwanto[1], N. Gomesh[1] and I. Safwati[2]

[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.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2014/11615
Editor(s):
(1) José Alberto Duarte Moller, Center for Advanced Materials Research Complejo Industrial Chihuahua, Mexico.
(2) Luigi Rodino, Faculty of Mathematical Analysis, Department of Mathematics, University of Turin, Italy.
Reviewers:
(1) Anonymous, Electronics Research Institute, National Research Center Building, Cairo, Egypt.
(2) Guanjun Ding, Beijing Information Technology Institute, Beijing, China.
(3) Anonymous, Da-Yeh University, Taiwan.
(4) Anonymous, University of Engineering and Technology Taxila, Pakistan.
(5) Ranjit Singh Sarban Singh, Universiti Teknikal Malaysia Melaka, Malaysia.
(6) Anonymous, Central University of Technology, South Africa.
(7) Logerais Pierre-Olivier, CERTES, Université Paris-Est Créteil, IUT de Sénart, France.
Peer review History: http://www.sciencedomain.org/review-history.php?iid=632&id=22&aid=5957

Original Research Article

Received 25th May 2014
Accepted 14th August 2014
Published 6th September 2014

ABSTRACT

Aims: The purpose of this paper is to design a solar cooling system to decrease operating temperature of PV module in order to improve the efficiency of PV output power. The usage of solar photovoltaic (PV) technology is a very attractive method for renewable energy. This study effort with going towards renewable energy can solve non-renewable energy issues. The efficiency of PV module is influenced by solar irradiance and ambient temperature. When temperature is increasing, output current will increase

**Corresponding author: E-mail: leowwaizhe@gmail.com;*

but output voltage and power will decrease and vice versa. When the solar irradiance increase, output current and power will increase with linear and output voltage will increase with marginal and vice versa. DC brushless fan and water pump (DC Hybrid cooling system) with inlet/outlet manifold are designed for constant air movement and water flow circulation at the backside and front surface of PV module. The DC hybrid cooling system with PIC controller is a solution to solve the problem of low efficiency of PV module in order to generate more electrical energy compared to PV module without cooling system.
Study Design: A solar cooling system is designed, developed and experimentally investigated.
Place and Duration of Study: Centre of Excellence for Renewable Energy, University Malaysia Perlis (UniMAP), between November 2013 and April 2014.
Methodology: To make an effort to cool the PV module, DC brushless fan and water pump with inlet/outlet manifold are designed for constant air movement and water flow circulation at the backside and front surface of PV module. Temperature sensors were installed on the PV module to sense temperature of PV module. A microcontroller system as PIC 18F4550 was utilized to manipulate the DC hybrid (DC fans and DC water pump) for switch ON and OFF based on temperature PV module automatically. The overall performances of PV module with and without cooling system are presented during this experiment respectively.
Results: The PV module with DC hybrid cooling system increase 4.99%, 39.90%, 42.65% in term of output voltage, output current, output power and decrease 6.79ºC compared to PV module without DC hybrid cooling system. The efficiency of PV module with cooling system was improved as compared to PV module without cooling system, the reason being that the ambient temperature decreased considerably. This Hybrid solar cooling system by using PIC controller is an intelligent system due to fact that the PIC controller will switched ON solar cooling system when the system is necessary.
Conclusion: An increase in efficiency of PV module, investment payback period of the solar system is able to minimize along with the lifespan of PV module are also able to be prolonged. By adding PIC controller, it is able to control the power switch of cooling system automatically. Thus, the system is lead to energy saving.

Keywords: Cooling system; PIC controller; ambient temperature; solar irradiance; photovoltaic.

1. INTRODUCTION

Energy is an important factor for the human growth. At the same time, production of energy can cause environment damage which is global warming, air pollution, water pollution, and climate change and so on. Energy is classified into two categories of renewable energy sources and non-renewable energy sources. Non-renewable energy also called as conventional energy, for example natural gas, coal and oil. As development outcomes of world economy and the increasing energy needs, the energy of conventional is swiftly increasing. Non-renewable energy composed major of carbon and hydrogen. Non-conventional energy also known as renewable energy for instance solar energy, wind energy, tidal wave energy and hydropower. Both of the greater numbers of chemical reactions discharge heat power. If the non-conventional energy is highly demand among peoples, the requirement of conventional energy will be reduced. The utilization of non-conventional energy provides the best way to eliminate the effect of global warming.

PV power generation is one of the available choices of renewable energy that is becoming widely utilized in our globe. This method of electric power generation is essentially generating electrical power by converting solar irradiation into direct current electricity with the presence of semiconductors in the PV modules that display PV effect. PV is an interesting energy; it is alternative, abundant, silent and environmental friendly. PV technology is a very useful option for renewable energy, as it would be a natural resources and pollution-free. At the same time, PV technology can also reduce greenhouse gas emission. Silicon semiconductor is the usual material of PV cell. In general, three major types of technology are used in the production of PV cells: monocrystalline; polycrystalline; and amorphous silicon [1]. The scope of conversion efficiencies and as result efficiencies of electrical power from sun power for monocrystalline is 12%-20%. The conversion efficiencies for polycrystalline are in scope of 10%-18%; at the same time as the scope of conversion efficiencies for amorphous is 6%-9%.

The efficiency of the PV module is depending on solar irradiance and ambient temperature. Bashir, M.A, Ali, H.M, Khalil, S, Ali, M. and Siddiqui, A.M. [2] discussed that module temperature depends upon solar irradiance as well as ambient temperature. The module efficiency of PV modules at outdoor conditions is different from STC due to varying outdoor conditions [2]. When the ambient temperature of PV module increase, the PV module efficiency decreases and vice versa. Due to the fact power is equivalent to voltage multiply current this property means that the warmer the solar panel the lesser power is generated. The power loss due to temperature is also dependent upon the variety of solar panel being used. When solar irradiance of PV module increases, the PV module efficiency also increases. Solar irradiance is depending on current output of a PV module and it is in fact linear. In the other hand, the voltage output is increased and does not changed dramatically. Skoplaki and Palyvos [3] presented that a key variable for the PV conversion process is the operating temperature of the cell/module. Tiwari and Sodha [4] reported that one of the main reasons for reduction of electrical efficiency of the PV module is the increase in the temperature of the PV module due to solar radiation. Another study by Tiwari and Sodha [5] wrote that in order to increase the efficiency of the PV module, the temperature of the PV module should be decreased. Rustemli and Dincer [6] discussed that increasing of panel temperature is affected electricity generation capacity of PV panels and as the panel temperature is increasing, current is very little increased but voltage is decreased. Ye et al. [7] noted that the efficiency of PV modules is strongly affected by their operating temperature. Trinuruk et al. [8] mentioned that the temperature of PV cells is one of the most important parameters for assessing the long term performance of PV module systems and their annual amounts of electrical energy production.

The manufacturers of PV modules provided general reference values for specified operating condition such as STC (Standard Test Conditions) for which the irradiance level is 1000 W/m² and the cell temperature is 25ºC. Real operating conditions are always different from the standard conditions, and mismatch effects can also affect the real values of these mean parameters [9]. Several varying PV performance parameters like current, voltage and power are presented in the temperature coefficient. With respect to the influence of temperature in the standard test conditions (STC) of PV modules is determined by the temperature coefficient. Rate of change of the temperature coefficient associated with different temperature of parameters of PV performance. For instance, open-circuit voltage (V_{oc}), maximum power voltage (V_{pm}), short-circuit current (I_{sc}), maximum power current (I_{pm}), maximum power (P_m), fill factor (FF) and efficiency (η) will affect the rate of temperature coefficient. When the temperature increase, output voltage will decrease with drastic and output current will increase with marginal. FF also decreases all these lead to an overall decrease in the cell efficiency [1].

Using concept of water cooling system, a layer of water is able to flow on the PV module to provide cooling down outcomes. Odeh S. [9] presented 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. This process offers an inclination for the module to remain cooled and close to ideal ambient temperatures, hence improving the PV system efficiency [10].

Krauter [11] investigated a method of reducing reflection with a thin (1mm) film of water running over the face of the panel. The improved optics and cell temperatures increased electrical yield 10.3% over the day. Hosseini et al. [12] compared the performance of a PV system combined with a cooling system and found that the system yielded higher output. Abdolzadeh and Ameri [13] obtained improved electrical efficiency by spraying water on top surface the panel as a result of decrease in cell temperature.

Sanusi et al. [14] investigated the effect of ambient temperature on PV modules for three years and found a linear behavior between output power and ambient temperature. Some unavoidable environmental factors including wind speed and direction, dust accumulation, humidity, and ambient temperature also affect the performance of PV modules [15,16].

H.G Teo et al. [17] reported the efficiency of different configurations of PV module. Without active cooling, the temperature of the module was high and solar cells can only achieve an efficiency of 8-9%. However, when the module was operated under active cooling condition, the temperature dropped significantly leading to an increase in efficiency of solar cells to between 12% and 14% [17]. Teo et al. [17] designed and fabricated a hybrid photovoltaic/thermal (PV/T) solar system. To actively cool the PV cells, a parallel array of ducts with inlet/outlet manifold designed for uniform airflow distribution was attached to the back of the PV panel.

Arab, A. [18] reported the water spraying is atomized by control system and spraying unit. The control system includes temperature sensor and microcontroller circuit. Dan M. J. Doble [19] reported 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.

W.G Anderson et al. [20] discussed a cooling design that uses a copper/water heat pipe with aluminum fins to cool a Concentrating PV Cells (CPV) by natural convection. Heat pipe can be used to passively remove the heat, accepting a high heat flux at the CPV cell, and rejecting the heat to fins by natural convection, at a much lower heat flux. This work successfully demonstrated the feasibility of a heat pipe cooling solution for CPV [20].

Sheyda et al. [21] reported experimental data from performance of two-phase flows in a small hybrid micro channel solar cell. Using air and water as two-phase fluid, the experiments were conducted at indoor condition in an array of rectangular micro channels with a hydraulic diameter of 0.667mm.

Suresh V et al. [22] investigated the operating temperature plays a vital role in the photovoltaic conversion. Both the electrical efficiency and the power output of a PV module linearly depend on the operating temperature. Evaporative coolers are used with solar panel to reduce panel temperature, thereby increasing power output.

Furushima and Y. Nawata [23] evaluated the performance of PV-power generation system equipped with a cooling device utilizing siphon age. The study showed that the cooling of PV modules increased the electrical power output and produced hot water which could be for heating purposes thereby contributing for an energy efficient system. Tripanagnostopoulos et al. [24] studied hybrid PV/T solar systems experimentally and used water and air to extract heat from the rare surface of the PV module.

Kelley et al. [25] assembled a flat plate heat exchanger to the non-active surface of a PV module used for powering a reverse-osmosis desalination unit, which desalinated the cooling sea water. Water cooling enhanced both PV electrical output and the production rate of desalinated water. Eveloy V et al. [26] discussed a motor driven pump was required to circulate and pressurize the cooling water for desalination. The reduction in PV module operating temperature due to cooling permitted the incorporation of low-cost flat-plate concentrating mirrors. The system was automated to control both water flow rate and temperature. It was also suggested that a portion of the physical energy of the pressurized desalinated water could be recuperated using an additional recovery device (e.g., turbine).

Mohammed. Sh-Eldin et al. [27] reported solar chimney utilizes solar radiation to increase the air flow temperature which works as passive cooling PV panel through air flow in the channel. The heat lost to the air gap heats up the air which cools the PV panel and the preheated air is channeled through proper solar chimney systems design.

Gardas and Tendolkar [28] used seven gasses for cooling in PV/thermal system; they found that hydrogen to be the best gas to maximize the output power of the system. Chinamhora et al. [29] 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 [30] 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. Arab, A. reported the water spraying is atomized by control system and spraying unit. The control system includes temperature sensor and microcontroller circuit [31].

Sharp Solar Module ND-130T1J has been chosen to analysis PV modules performance in this investigation. The most important focus is on the comparison and review of the efficiency of the PV module with and without cooling system. Furthermore, the second aim of this study is to observe the impact of the solar radiation and temperature on their output parameters.

2. METHODOLOGY

Fig. 1 shows the block diagram overview of the DC hybrid cooling system. In order to fulfill the requirement of investigation, the solar energy is selected as a main source of this project. The PV module produces electrical energy and supplies DC source to battery charger. The output power of PV module is used to charge the 12 V_{DC} lead acid batteries (model is SLA-12-70, 12 V_{DC}, capacity is 7.0 Ampere-hour. In a PV system, a common lead battery has an operational life no more than 5-6 years.) by using battery chargers. It continuously charge the battery until it shows at the sign of full status on and will cut-off charging process. The utilization of battery is used to keep electrical energy that produced by PV module. Battery supplies DC source to DC water pump that is placed in front of PV module and DC fans that placed at the back of PV module. DC water pump and DC fans as PV cooling system to decrease temperature for improving efficiency output power of PV module. Besides, the output of the PV module power DC lamp (12 V_{DC}, 75W) as a load.

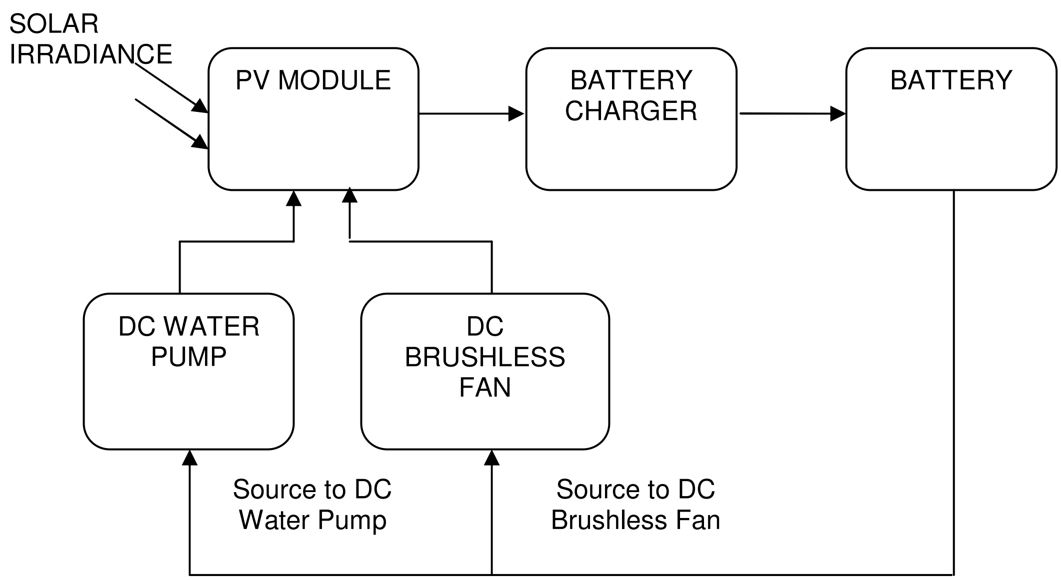

Fig. 1. Block diagram overview of the DC hybrid cooling system

Fig. 2 displays flow chart of the PIC controller system. The system operates as the following step. It starts with the initialization on most details desired because of the application, after that initializes LCD to indicate the process starts to function. The system after that enables serial disrupt along with ADC to read temperatures via LM 35 sensor. The temperatures of PV module are usually as compared to setting level (35ºC). In case any temperature sensor detected PV module temperatures is usually preceding 35ºC, then the threshold is usually incremented through 1 (to 36ºC) and it will to switch ON the DC cooling system. When all of temperature sensor detects temperature of PV module below than setting level (35ºC), the DC cooling system will switches OFF in order to avoid waste power. All the PV module temperatures were displayed on the LCD.

LM 35 sensor is chosen because LM35 is more accurate compared to a thermistor and it puts out higher voltage compared to a thermocouple, minimizing the opportunity that the voltage needs to be induced. Moreover it utilizes very little power, so it does not warm up.

In this investigation, two Sharp Solar Module ND-130TIJ polycrystalline solar modules were used to convert sunlight energy into electrical energy. Two Sharp Solar Module ND-130T1J were used with 130W peak power, 22.0V $V_{oc,}$ 8.09A $I_{sc,}$ module efficiency is 13% under STC as shown in Table 1. The parameter of DC brushless fans and DC water pump was shown in Tables 2 and 3 respectively. A PV module installed DC hybrid cooling system with a DC lamp (75W) while another PV module without DC hybrid cooling system with a DC lamp (75W) respectively as shown in Fig. 3. The PV modules should face to the south with the tilt angle of 6.29º [32].

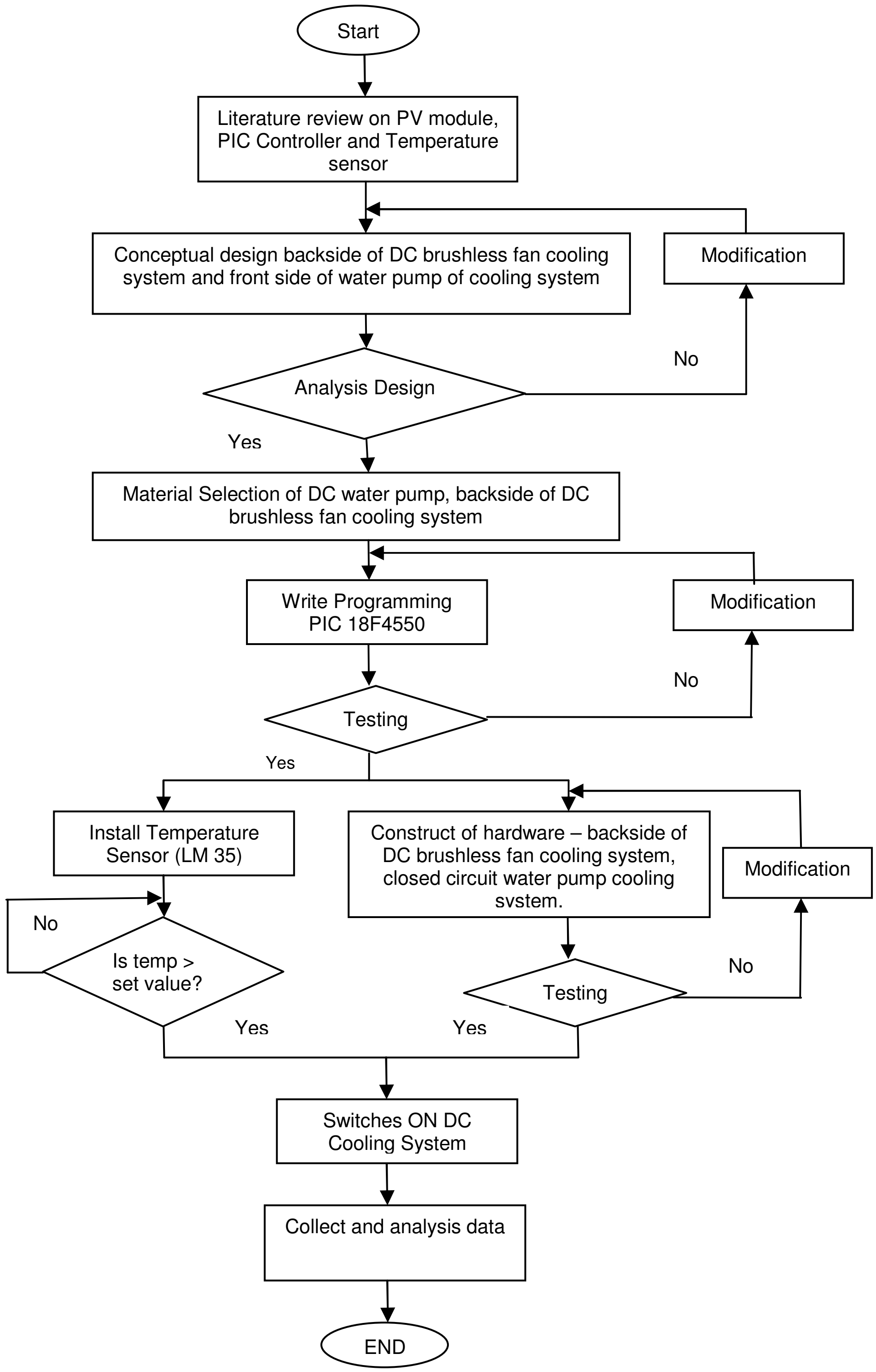

Fig. 2. Flow chart of the PIC controller system of DC hybrid cooling system

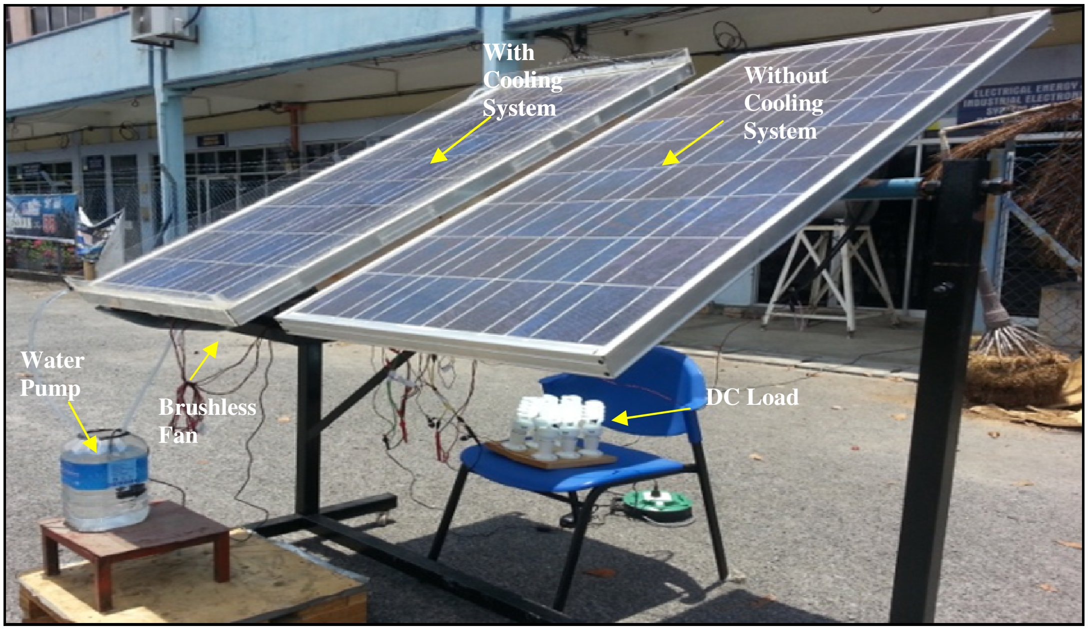

Fig. 3. DC hybrid cooling system

Besides that, the DC hybrid cooling system is controlled by control system which is microcontroller circuit and temperature sensors. LM 35 as temperature sensor is placed on the back side of the PV module. Four temperature sensors are installed at each PV module where two temperature sensors at the top side and another two temperature sensors at the top bottom of PV module. The data of temperatures were measured and recorded by using Midi Logger GL220 in every ten minutes. Function of PIC 18F4550 microcontroller is to switch ON and OFF the hybrid cooling system automatically. When the temperature of PV module is equal or more than 35 ˚C that detected by LM 35, the PIC 18F4550 is switched ON the hybrid cooling system and vice versa. After switch ON the cooling system, the water pump was spraying on the front of PV module and two fans were blow on the back sides of PV module in the same time. Mean that the DC fans cool down the temperature of PV module backside while DC water pump cool down temperature of PV module front side in the same time. This controller system is an intelligent system because it will run the cooling system when the temperature of PV module reaches setting level that detected by temperature sensors automatically and avoid waste electrical energy.

The output voltage of both PV modules were measured and collected by using Midi Logger GL220 also and the output current of both PV modules were measured and recorded by using Digital Multimeter in every ten minutes as shown in Fig. 4. A Davis Vantage PRO2 Weather was used to determine the daily ambient temperature and solar irradiance.

Table 1 shows the characteristic of the PV module (Sharp solar module ND-130T1J); while Tables 2 and 3 displays the parameter of the DC brushless fan and DC water pump respectively.

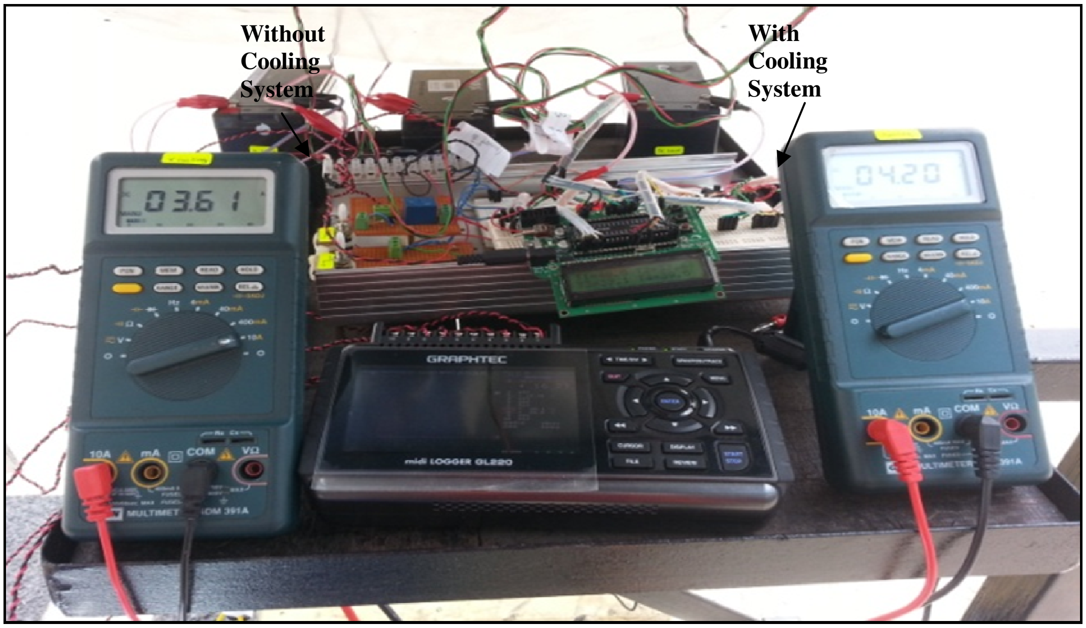

Fig. 4. Setup experiment with measurement devices

Table 1. The characteristic of the sharp solar module nd-130t1j

Parameters	Symbol	Value	Unit
Open circuit voltage	V_{oc}	22.0	V
Maximum power voltage	V_{pm}	17.4	V
Short circuit current	I_{sc}	8.09	A
Maximum power current	I_{pm}	7.48	A
Maximum power	P_m	Min. (123.5) Typical (130)	W
Module efficiency	η	13.0	%
No. of cells and connections	-	36 in series	-

Table 2. The parameters of the dc brushless fan (dc-xcase120)

Specification	Value
Overall dimension	120X120X25MM
Fan dimension	120X120X25MM
Rated voltage	12VDC
Rated current	0.07±10%A
Power input	0.84W
Operating voltage	10.8~13.2VDC
Started voltage	7VDC
Fan speed	1300±10%RPM
Max. air flow	44.71CFM
Noise	26DB(A)

Table 3. The parameters of the dc water pump (wp12v-001)

Specification	Value
Rated voltage	3.5 V to 12 V DC
Rated current	65 mA-500mA
Max volume	350 L per hour
Size	3.75x3.71x3.3cm
Inner diameter	5.9mm
Outer diameter	8.3mm
Life span	20000 hours

3. RESULTS AND DISCUSSION

This investigation was conducted at Centre of Excellence Renewable Energy (CERE) on 31 March 2014 from 9:00 a.m until 5:00 p.m. The DC hybrid cooling system was experimented at the outdoor CERE.

Fig. 5 shows solar radiation and ambient temperature on 31 March 2014. The PV modules were observed within November 2013 and April 2014. But the best of output performance of the day has been chosen to be analyzed in this experimental. The maximum solar radiation occurs at 15:48 p.m which was 4752Wh/m² and the maximum ambient temperature was 33.6ºC which occur at 13:47 p.m which shown in the Davis Vantage PRO2 Weather.

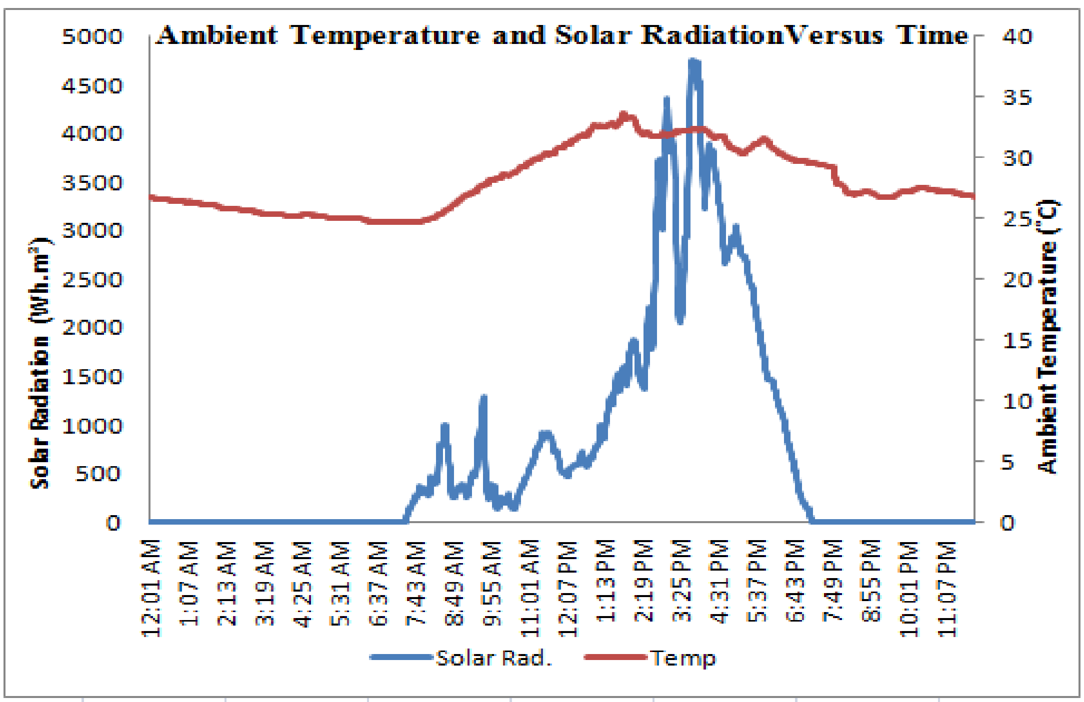

Fig. 5. Solar radiation and ambient temperature on 31 March 2014

Fig. 6 shows ambient temperature of PV module versus time for PV module with DC hybrid cooling system and PV module without DC hybrid cooling system. The maximum temperature of PV module with cooling system was reached at 45.9ºC in 1:00 p.m and average temperature was 40ºC while the maximum temperature of PV without cooling system was reached at 55.1ºC in 14:40 p.m and average temperature was 46.79ºC. The temperature variation of PV module without cooling system was increased by 6.79ºC compared to PV module with cooling system. Performance of PV module can be affected by ambient temperature.

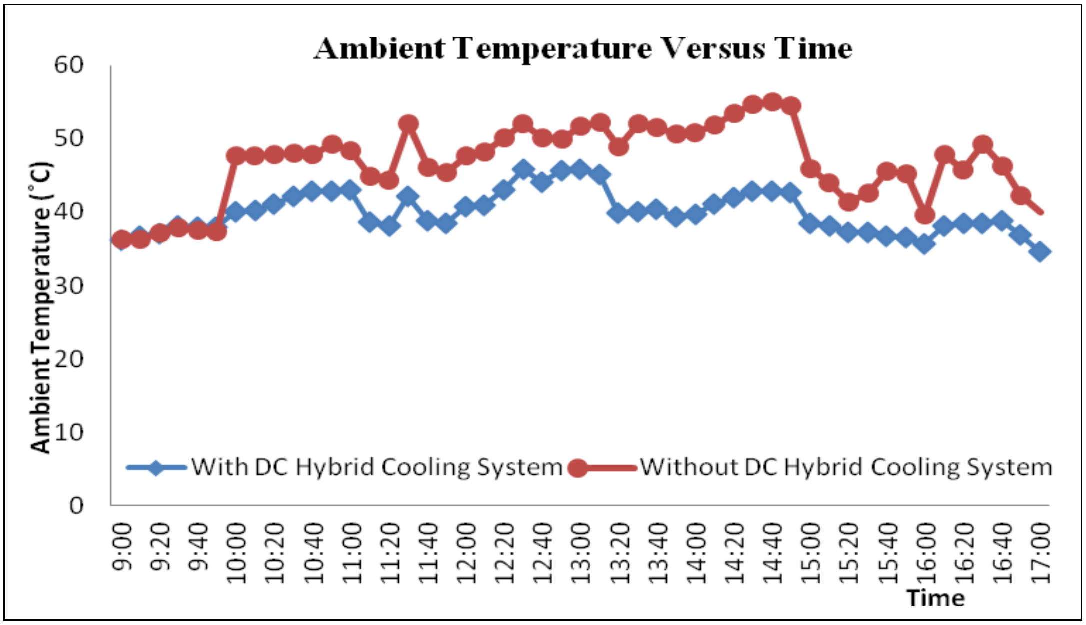

Fig. 6. Ambient temperature of PV module versus time for PV module with and without DC hybrid cooling system

Fig. 7 shows output voltage versus time for PV module with and without DC hybrid cooling system. Figure displays the maximum output voltage of PV module with DC hybrid cooling system was 17.33V while the minimum output voltage of PV module with DC hybrid cooling system was 12.13V. Solar radiation was in no strong condition and some of PV cells cannot generated more output that affected the output voltage decrease in this situation. The average output voltage of PV module with DC hybrid cooling system was 15.67V. Besides that, maximum output voltage of PV module without DC hybrid cooling system was 17.31V and minimum output voltage was 11.52V. The average of output voltage of PV module without DC hybrid cooling system was 14.89 V. The comparison between both the systems, the output voltage increased 4.99% when using of PV module with DC hybrid cooling system. This is due to the ambient temperature of PV module surface with DC hybrid cooling system decrease; the output voltage of this PV module was increased.

Fig. 8 shows output current versus time for PV module with and without DC hybrid cooling system. Current play main role in PV module because it was determined by the time need to complete charging the battery and to run DC loads. It can be observed maximum output current that produced by PV module with cooling system was 7.16 A while the minimum output current was 2.09 A. The average output current was 5.15 A. In the same time, the maximum output current of PV module without cooling system reached was 3.98 A while the minimum output current displayed at 1.28 A. 3.09 A was the average output current of PV module without cooling system. In the comparing result among both systems, the output current increased 39.90% when using cooling system. In the result, it can be observed that when temperature and solar irradiance increase, the output current also increased. So, the output current increased in major percentage compared to output voltage when using cooling system.

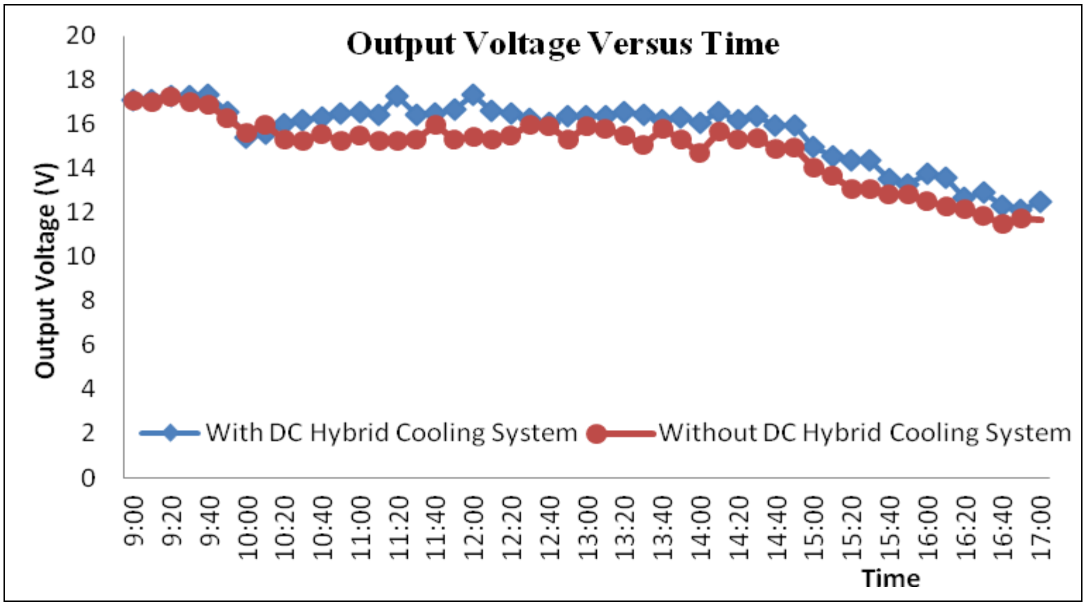

Fig. 7. Output voltage versus time for PV module with and without DC hybrid cooling system

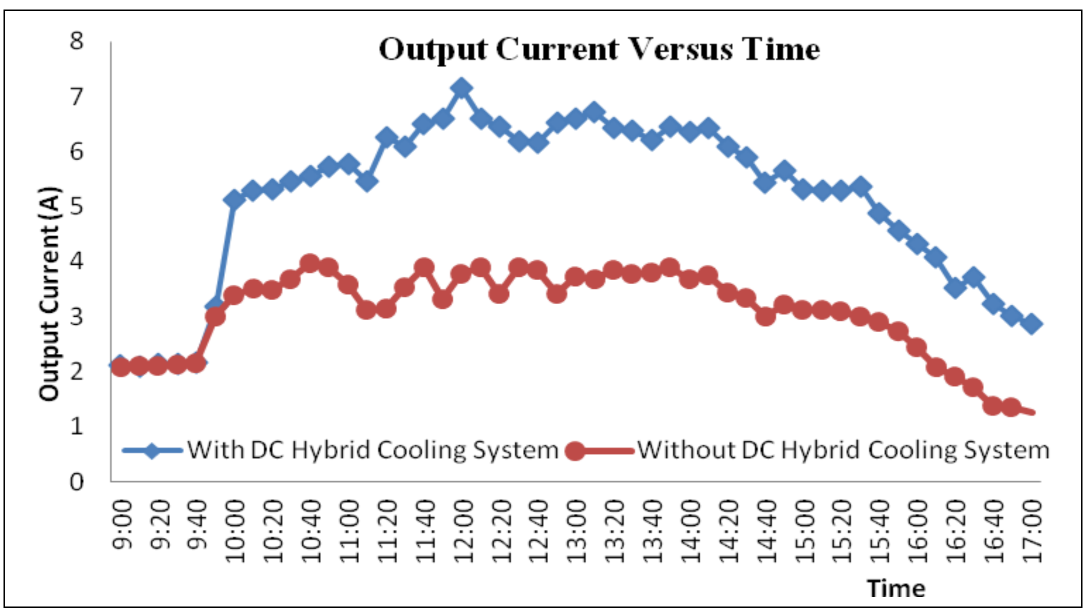

Fig. 8. Output current versus time for PV module with and without DC hybrid cooling system

Fig. 9 shows output power under PV module with DC hybrid cooling system and PV module without DC hybrid cooling system. The output power of with and without cooling system gained in units of electricity has been measured and calculated from the hours of exposure of the PV module to the solar irradiance. It can be observed that output voltage and current are directly proportional to output power.

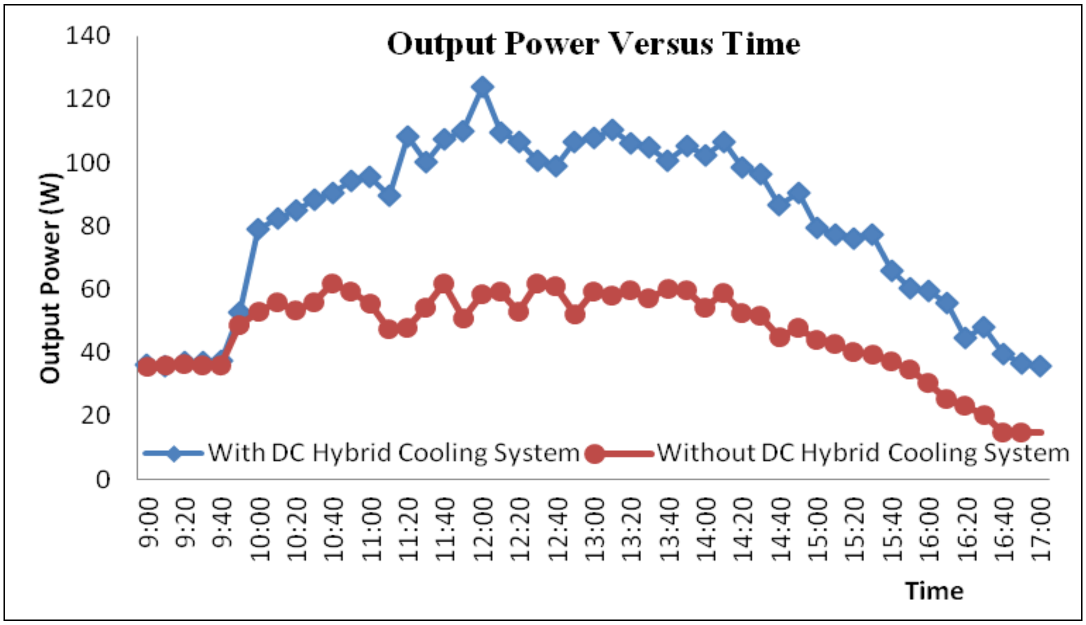

Fig. 9. Output power versus time for PV module with and without DC hybrid cooling system

In the PV module with cooling system, the output power was slightly increased from 9:00 a.m and reached at maximum point at 12:00 p.m and then decreased until 5:00 p.m. The changing of solar irradiance and ambient temperature that affect that output power cannot maintain stable. This condition occurs because of the impact of winds and clouds. They act as barriers to the intensity of light. The maximum output power was measured and calculated at 124.0828W while the minimum output power was 35.29W. The average output power of PV module with cooling system was 81.33W.

In the other sides, the output power of PV module without cooling system was below than 65W. From the Fig. 9, it can be determined output power starting increased and reached maximum point at 62.16W which is at 11:40 a.m and then decreased until 5:00 p.m. The PV module without cooling system produced 14.95W as a minimum output power. The average output power of PV module without cooling system was 46.64W. The increase percentage in the output power in unit of electricity by using PV module with cooling system is calculated to be 42.65%.

The current result compared reasonably well with the experimental result from Z. Farhana [33] as shown the output power of PV with DC brushless fan cooling system is increases 8.56W compared to PV without DC brushless fan cooling system. In my investigation, the output power of PV with DC hybrid cooling system is increased 34.69W compared to PV without DC hybrid cooling system. By using PV with DC hybrid cooling system, PV module can be generated more output power compared to PV with DC brushless fan cooling system or PV with DC water pump cooling system only.

According H.G Toe's investigation, the active cooling mechanism was running in the whole day and wasting unnecessary energy. The comparison between my investigation and H.G Teo's investigation, DC hybrid cooling system with PIC controller will be run when the temperature of PV module reached setting levels that detected by temperature sensors automatically and avoid waste electrical energy. By adding PIC controller, the DC hybrid cooling system can be saved more energy. This is because the cooling system will switched ON or switched OFF which controlled by PIC controller when necessary only. The duration of output power of PV module for charges full battery is one and hall hours and it cut-off the charging process when the battery is in full condition.

By adding DC hybrid cooling system to PV module, the cost of DC cooling system installation will be considered. The total cost of DC hybrid cooling system of one PV module installation is RM 213.00 which is a small amount compared to cost of 1kW PV power plant installation (RM 10000.00). Besides, after applied DC hybrid cooling system on the PV modules; the PV modules with DC cooling system can be generated more output power compared to PV modules without DC cooling system as mentioned statement above.

4. CONCLUSION

The goal achieved through this paper has presented DC hybrid is used as a cooling equipment for this PV module cooling system. PIC 18F4550 microcontroller is to control the cooling system that detected by LM 35 either switches ON or switches OFF cooling system automatically. When the temperature of PV module is equal to or more than 35ºC that detected by LM 35, the PIC 18F4550 is switched ON the DC hybrid cooling system while the temperature of PV module below than 35ºC that detected by LM 35, the PIC 18F4550 is switched OFF the DC hybrid cooling system. Solar irradiance and ambient temperature are the effect of the efficiency of PV module. When temperature increase, output current will increase but output voltage and power will decrease and vice versa. When the solar irradiance increase, output current and power will increase with linear and output voltage will increase with marginal and vice versa. The comparison between both systems, the PV module with DC hybrid cooling system increase 4.99%, 39.90%, 42.65% in term of output voltage, output current, output power and decrease 6.79 ˚C compared to PV module without DC hybrid cooling system. More efficiency associated with PV module, investment payback period of the system can minimize and the lifespan associated with PV module can be prolonged. By adding PIC controller, it is able to control the power switch of cooling system automatically. Thus, the system is lead to energy saving.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. AC Moreira Soares, et al. Simulation of a photovoltaic model using bisection method. 2011;807-811.

2. Bashir MA, Ali HM, Khalil S, Ali M, Siddiqui AM. Comparison of performance measurements of photovoltaic modules during winter months in Taxila, Pakistan, Article ID 898414, International Journal of Photoenergy; 2014.
3. Skoplaki E, Palyvos JA. Operating temperature of photovoltaic modules: A survey of pertinent correlations. Renewable Energy 2009;34(1):23–9.
4. Tiwari A, Sodha MS. Performance evaluation of hybrid PV/thermal water/air heating system: A parametric study. Renewable Energy. 2006;31:2460–74.
5. Tiwari A, Sodha MS. Performance evaluation of solar PV/T system: An experimental validation. Solar Energy. 2006;80:751–9.
6. Rustemli S, Dincer F. Modeling of photovoltaic panel and examining effects of temperature in Matlab/Simulink. Elektronika Ir Elektrotechnika (Journal of Electronics and Electrical Engineering). 2011;3(109):35–40.
7. Ye Z, Nobre A, Reindl T, Luther J, Reise C. On PV module temperatures in tropical regions. Solar Energy. 2013;88:80–7.
8. Trinuruk P, Sorapipatana C, Chenvidhya D. Estimating operating cell temperature of BIPV modules in Thailand. Renewable Energy. 2009;34(11):2515–23.
9. W Zhu, et al. Modeling and analysis of output features of the solar cells based on MATLAB/Simulink. 2011;730-734.
10. Odeh S, Behnia M. Improving photovoltaic module efficiency using water cooling, taylor and francis Ltd, Heat Transfer Engineering. 2009;30:499–505.
11. Krauter S. Increased electrical yield via water flow over the front of photovoltaic panels. Solar Energy Materials & Solar Cells. 2004;46:131-137.
12. Hosseini R, Hosseini N, Khorasanizadeh H. An experimental study of combining a photovoltaic system with a heating system. World Renewable Energy Congress, Sweden; 2011.
13. Azadeh K. The effects of nominal power of array and system head on the operation of photovoltaic water pumping set with array surface covered by a film of water. Renewable Energy. 2010;35:1098–1102.
14. Sanusi YK, Fajinmi GR, Babatunde EB. Effects of ambient temperature on the performance of a photovoltaic solar system in a tropical area. The Pacific Journal of Science and Technology. 2011;12(2):176–180.
15. Mani M, Pillai R. Impact of dust on solar photovoltaic (PV) performance: Research status, challenges and recommendations. Renewable and Sustainable Energy Reviews. 2010;14(9):3124–3131.
16. Jiang H, Lu L, Sun K. Experimental investigation of the impact of airborne dust deposition on the performance of solar photovoltaic (PV) modules. Atmospheric Environment. 2011;45(25):4299–4304.
17. Teo HG, Lee PS, Hawlader MNA. An active cooling system for PV modules. Applied Energy. 2012;90:309-315.
18. Arab A, Chenlo F, Benghanem M. Loss-of-load probability of photovoltaic water pumping systems. Solar Energy. 2004;76:713-23.
19. Doble DMJ. Minimization of reflected light in photovoltaic module. Renewable Energy World. Article 03; 2013.
20. Anderson WG, Dussinger PM, Sarraf DB, Tamanna S. Heat pipe cooling of concentrating PV cells. PV Specialists Conference. 2008;1-6.
21. Sheyda PV, Rahimi M, Karimi E, Asadi M. Application of two-phase flow for cooling of hybrid microchannel PV cells: A comparative study, Energy Conversion and Management. 2013;69:122–130.
22. Suresh V, Naviynkumar S, Kirubakaran V. Improved power output of PV system by low cost evaporative cooling technology. International Conference on Green Computing, Communication and Conservation of Energy (ICGCE); 2013.

23. Furushima K, Nawata Y. Performance evaluation of photovoltaic power-generation system equipped with a cooling device utilizing Siphonage. Journal Solar Energy Engineering ASME. 2006;128(2):146-151.
24. Tripanagnostopoulos Y, NousiaTh M, Souliotis, Yianoulis P. Hybrid photovoltaic/thermal solar systems. Solar Energy. 2002;72(3):217–234.
25. Kelley L, Bilton AM, Dubowsky S. Enhancing the performance of photovoltaic powered reverse osmosis desalination systems by active thermal management. Proceedings of the ASME 2011 International Mechanical Engineering Congress & Exposition (IMECE2011), November 11-17, Denver, Co., USA, Paper No. IMECE2011-62717; 2011.
26. Eveloy V, Rodgers P, Bojanampati S. Enhancement of photovoltaic solar module performance for power generation in the Middle East. Semiconductor Thermal Measurement and Management Symposium (SEMI-THERM), 2012 28th Annual IEEE; 2012.
27. Mohammed Sh-eldin, Sopian K, Fatah O. Alghoul, Ahmed N. Abdlla, Adnan M, Ae. Muftah. The optimum solar chimney structure to improve photovoltaic system efficiency. Computer Applications in Environmental Sciences and Renewable Energy; 2014.
28. Gardas BB, Tendolkar MV. Design of cooling system for photovoltaic panel for increasing its electrical efficiency. International Journal of Mechanical and Production Engineering (IJMPE). 2012;1:63-67.
29. Chinamhora T, Cheng G, Tham Y, Irshad W. PV panel cooling system for Malaysian climate conditions. International Conference on Energy and Sustainability. Karachi, Pakistan; 2013.
30. Gheorghe Asachi. Combined photovoltaic and thermal solar panels-enhanced energy conversion and heat transfer. Termotehnica. 2013;135-140.
31. Arab A, Chenlo F, Benghanem M. Loss-of-load probability of photovoltaic water pumping systems. Solar Energy. 2004;76:713-23.
32. Irwanto M, Daut I, Sembiring M, Ali R, Champakeow S, Shema S. Performance of PV module at different tilt angles in perlis. Northern Malaysia. International Postgraduate Conference on Engineering (IPCE 2010), University Malaysia Perlis (UniMAP); 2010.
33. Daut I, Farhana Z, Irwan YM, Razliana ARN. Investigation of photovoltaic modules cooling system. 2nd International Malaysia-Ireland Joint Symposium on Engineering, Science and Business (IMIEJS); 2012.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=632&id=22&aid=5957