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Optimum Number of DC Fan as a Cooling Medium for Photo Voltaic (PV) System

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Abstract: In real practical PV panel operation a major part absorption of solar radiation is wasted as a heat energy which causes an elevated operating temperature. It is necessary to cool the PV panel by extracting the extra heat generated from the PV panel in some way. The aim of this present study is to determine the optimum number of DC fan as a cooling medium required for a unit PV panel. A formulation equation of heat extraction for selected type PV panel was carried out to calculate the required airflow of DC fan. Besides, temperature distribution subsequently analysed in outdoor weather conditions throughout a day as the purpose to calculate to heat needed to be removed. Based on the measurement and calculation the results clearly show how the capability of DC fan plays its role in extract the large amount of heat produced through PV panel. Results revealed that the number of DC fan for a selected unit of PV panel is determined by two units. In conclude, high rate of heats transfer fluid removes too much heat causes the temperature of the PV panel decreases, hence reducing the heat loss.

Key words: PV panel, PV panel temperature, solar radiation, Direct Current (DC), fan

INTRODUCTION

Not all absorption solar radiation from PV panel converted to electrical energy most 80% of them waste as heat energy (Zhang *et al*., 2014). Consequently, the accumulated heat energy increases the PV panel operating temperature, hence leads to drop in its electrical efficiency. The effectiveness working operation of a PV panel can be achieved by extracting out the heat energy produced. The rate of heat transfer in a certain direction depends upon the temperature difference between PV panel and surrounding temperature of site location. In order to reduce the temperature of the PV panel, alternatively, PV panel should be cooled by removing heat in some methods.

DC fan is widely used to extend life of the system by cooling off the heat of the system that familiar to electronic component (Burke, 2004). As the semiconductor is of the type electronic component a DC fan is a necessary act as cooling medium due to reduce PV panel temperature (Farhana *et al*., 2012) used 2.4 W of DC brushless fan inlet/outlet manifold attached to the backside PV panel in order to enhance the performance output of a panel. With the existing fan cooling, the PV panel temperature seem to be increased about 30% than ambient temperature instead 70% when no cooling attached (Farhana *et al*., 2012). By using fan to induce the movement of air in cooling PV panel about 15% increment of electrical power achieved by Hernandez *et al*. (2013) increases in power output causes by reduction in PV panel temperature of 15°C, respectively (Hernandez *et al*., 2013). Olympia and Herricos investigated the roles of three different operating and capacity of fan cooling methods on Building Integrated Photovoltaic (BIPV). The higher capacity of a fan resulted in decreasing the mean panel temperature as well as the increase in cell efficiency but did not exceed 9% due to low irradiation (Zogou and Stapountzis, 2011).

The application of DC fan is advantageous rather than (Alternating Current) AC fan cause by their simpler structure and longer lifespan. Besides, the application of DC fan required low power consumption and vibration, also experiences in minimum leakage of flux. In order to achieve the best performance working operation of DC fan for PV panel the required number of DC fan as a cooling medium must be determined as to minimize the energy consumption. This study is focused on the procedure and methodology on the selection number of DC fans required for a PV panel which depending on heat transfer rate, site's climatic weather and specification of equipment used.

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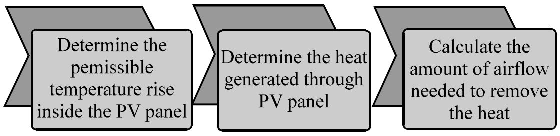

Fig. 1: Procedure in determine the number of DC fan

Formulation heat extraction of the PV panel

Procedure of calculating the required airflow for DC fan: The most important aspect of thermal management is selecting the required number of DC fan for cooling application. In selecting the number of DC fan for PV panel the amount of airflow needed to remove heat accumulated from the PV panel must be taken into consideration. Figure 1 shows the procedures to calculate the amount of airflow for DC fan required for PV system cooling application.

Heat transfer mode through PV panel: Heat is capable of being transmitted through the solids and fluids by conduction, empty space byradiation and through the fluid by convection. These three modes of heat transfer are involved through PV panel. Heat transfer rate due to conduction can be given as the sum of heat transfer of convection and radiation at the panel surface. As the heat transfer rate of radiation is very small at a lower temperature it can be neglected. Because of the PV panel constructed in the form of small contact area among its structural materials the heat loss due to conduction is negligible (Wilson and Paul, 2011). Convection heat transfer is classified according to the nature of the flow rate for free convection and forced convection. In this present study, heat loss has classified to be transferred from the backside surface PV panel through forced-air convection induced by DC fan. According to the Newton's Law of cooling, the total amount heat can be removed through the forced convection mode by using Eq. 1:

$$Q = h_{conv} A_s \Delta T \tag{1}$$

Where:

- Q = The total heat transfer rate (W) produced from the backside of PV module
- A_s = The surface area of the PV panel
- ΔT = Represents the difference in temperature between backside surface of the PV panel Temperature (T_{PV}) and ambient Temperature (T_{amb}) of testing location

The equivalent heat transferred coefficient (h_{conv}) for convection mode over the back side surface of PV panel is given by Eq. 2 (Onur, 1993):

$$h_{conv} = 5.7+3.8v \tag{2}$$

where, v represents for speed of wind in m/sec. The speed of DC fan identified as a speed for forced convection. Higher speed velocity increased the amount of heat transfer rates through PV panel.

Determine the required airflow of DC fan for heat removal of PV panel: Precise determination of airflow is the most important in proper selection of fan type and size. The airflow required depends on the process requirements; normally determined from heat transfer rates of the device. Based on the basic heat transfer equation such given in Eq. 3, the mass flow rate (m) of air is calculated due to determine the required air flow of DC fan. The mass flow rate can be defined as the amount of mass flowing through a cross-section of a flow device:

$$m = \frac{Q}{C_p \Delta T} \tag{3}$$

where, C_p is represented for specific heat capacity of air in J/kg.K is given by Cengel at the film Temperature (T_{film}) as be calculated through Eq. 4. Film temperature is the fluid temperature varies according to the details of the situation:

$$T_{film} = \frac{T_{PV}+T_{amb}}{2} \tag{4}$$

Where:

- T_{PV} = The average backside surface of PV panel
- T_{amb} = An ambient temperature of site experiment location

In order to determine the suitable number of DC fan used for a selected type of PV panel, the required airflow is calculated through Eq. 5. The necessary airflow of the DC fan is measured in Cubic Feet per Meter (CFM) at certain static pressure:

$$\text{Airflow}\left(\text{CFM}\right) = \frac{m}{p} \times 2119 \tag{5}$$

where, p is the density of air at the same previous film temperature (T_{film}) and 2119 is the constant value. Thus, from the calculated value of the airflow the selected DC fan as well as the required quantity can be identified for cooling the PV panel as well as reduce its temperature.

MATERIALS AND METHODS

As the purpose to determine the required heat can be removed through the backside PV panel the temperature distribution through PV panel has been analysed at outdoor condition as shown in Fig. 2. A 100 W monocrystalline PV panel cover with 0.648 m^2 of panel

Fig. 2: Photographic view for outdoor experimental

area tested at Centre of Excellence for Renewable Energy (CERE) located in Kangar, Perlis, Malaysia which lies on 6.43°N latitude and 100.19°E longitude, respectively. All data are measured and recorded from 9.00 a.m. to 5.00 p.m. for 10 min interval.

The electrical output generated from PV panel was measured using PROVA 200. Four units temperature sensor of LM 35 were attached at the backside surface of the PV panel as purpose to measure the average PV panel temperature of the day. Besides, the temperature distribution through PV panel has been captured using FLiR thermal camera on purpose to observe the surface temperature of the PV panel.

RESULTS AND DISCUSSION

Potential energy resources of site location: Climatic weather is a one of the factors influenced in determining the optimum number of DC fan for PV panel. Solar radiation is the main energy resources which strongly affected the amount power output produced from the PV panel. Figure 3 shows the potential of solar radiation during the experimental day. The amount of incoming solar radiations are much higher in duration 11 a.m. until 2 p.m. which can be determined as the peak sun of the day. There by it can be considered the site location has a big potential in installing the PV system (Irwan *et al*., 2015). The highest amount of solar radiation was found at 12.40 p.m. with 899.49 W/m^2 where the minimum amount found at 9.00 a.m. with 155.50 W/m^2. The low level of solar radiation might be due to a very short and a sudden blockage of the sun disk with too heavy clouds.

Generally an elevated value of solar radiation leads to the high ambient temperature. As can be observed in Fig. 3 the ambient temperature experiences at low temperature in the early morning with 28°C caused by the low intensity of radiation at 155.50 W/m^2. The ambient temperature during the experimental day starts to be increase with the increasing solar radiation. The maximum value found at radiation of 899.49 W/m^2 with 38.99°C while the average for a day is 35.11°C, respectively.

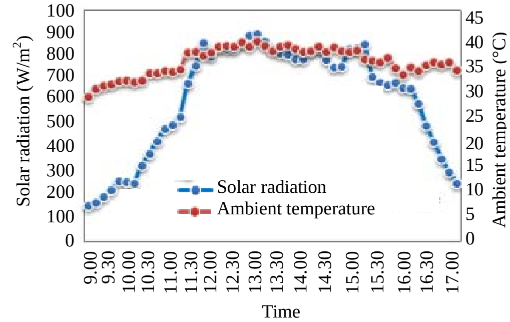

Fig. 3: The potential of climatic weather during the experimental day

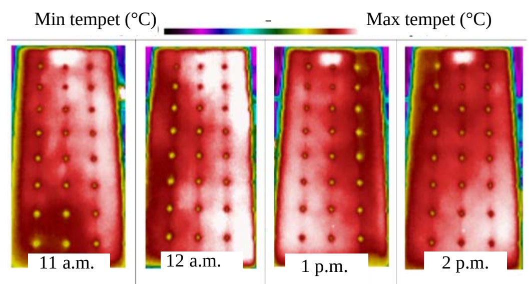

Fig. 4: Temperature distribution over the front surface of PV panel

Table 1: Temperature distribution over the front surface of PV panel

Time	Solar radiation (W/m^2)	T_{amb} (°C)	T_{min} (°C)	T_{max} (°C)	T_{av} (°C)	ΔT (°C)
11.00 a.m.	540.21	33.45	34.67	59.00	57.97	24.52
12.00 p.m.	832.50	37.99	36.13	66.15	63.55	31.48
01.00 p.m.	834.12	38.11	37.08	65.41	62.33	27.53
02.00 p.m.	833.62^d	37.13	37.92	63.75	62.11	26.20

Temperature distribution over the front surface PV panel: Heat is transferred only when there is a temperature difference between the heat source and the environment. Variation temperatures over the surface PV panel were captured during the peak sun hours which means from 11.00 a.m. to 2.00 p.m. is presented in Fig. 4. Thermography technique utilizes the cooler spots of the system by looking at the purple colored areas to the red zones. Table 1 explores the various temperature distributions during peak sun of the day which has been analysed using FliR ix series. The result reported that measured temperature ranges distributed from 34.67°-66.15°C, respectively. It clearly shows that large temperature differences (ΔT) along the panel surface sun period. Difference in these both Temperatures will contributes to the heat generated through the PV panel. Because of this condition the heat must be removed as the purpose to keep the PV panel temperature nearly the ambient temperature.

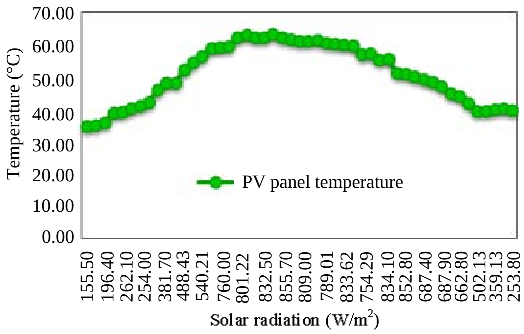

Fig. 5: Influence of solar radiation on PV panel temperature

Temperature distribution throughout the back surface at PV panel: An accumulated of PV panel temperature is strongly affected by the potential of ambient temperature and solar radiation. In real working operation, the majority of solar energy productions occurs when the PV panel temperature is mostly higher than ambient temperature. Figure 5 shows the various PV panel temperature at the backside surface of PV panel. As can be observed the temperature starts to increase when the solar radiation increase as well as the ambient temperature. There are so much differed between these two temperatures during peak's sun duration.

The maximum PV panel temperature found at 890.12 W/m^2 with 63.20°C while the minimum observed as 34.90°C at lowest solar radiation. Besides, the average PV panel temperature throughout the day is determined by 51.08°C, respectively. The increases in PV panel temperature rises due to higher insolation heating, low wind speed with the consequent despicable heat transferred from the panel to the ambient.

Identifying the optimum number of the DC fan: In order to produce the reliable forced-air cooling mechanism for PV panel, the necessary number of DC fan must be determined. By cooling mechanism with the optimum number of DC fan more electrical power output can be generated by the reduction of PV panel (Teo *et al*., 2012). The collected various of temperature distribution has been used to calculate the heat needed to be removed from PV panel. As heat expected to be extract from the backside PV panel the temperature distribution of the back surface is taken into account.

Without cooling mechanism attached the rate of heat loss increased with the rising in PV panel temperature causes by not enough heat is removed. By referring Eq. 1-2 the total heat transfer can be determined as knowing temperature distribution throughout outdoor experiment. As the DC fan will applied at the backside PV panel the temperature distribution on the back surface PV panel are taken into consideration.

Heat can be removed by natural convection generated through PV panel with the average wind speed of 2.5 m/sec (Irwanto *et al*., 2014) is calculated to be 2846.23 W. The low amount of heat transferred caused by low heat transfer rate with 15.2 W/m^2.K. In this present study, the selected type of DC fan used has 12 V of nominal voltage with rating current of 0.07±10% A and speed of 1300 RPM (8 m/sec). Furthermore, the DC fan can remove heat generated with their maximum airflow characteristic of 44.7 Cubic Feet per Minute (CFM), respectively. Therefore, by using the selected DC fan about 6759.81 W of excessive heat from PV panel can be extracted with 36.2 W/m^2.K of heat transferred coefficient.

Higher speed of wind contributes to the high heat rate of heat transfer. The optimum number of DC fan further can be identified as the required airflow has been determined by referring Eq. 3-5. Based on the heat generated the required airflow of DC fan is calculated to be 44.39 CFM. But the motion air flow when the fan motor is actually mounted on system can be obtained using the air flow-static pressure characteristics curve and system impedance. However, the system impedance cannot be measured without a measuring equipment so fan with 1.5-2 times higher air flow than the calculated air flow should be selected. Thus the optimum number of DC fan for selected type PV panel is determine by two units as the DC fan has potential to generate about 44.7 CFM per unit at zero pressures for a unit.

CONCLUSION

In short, this study determined the optimum number of DC fan for a unit PV panel. The role of DC fan as a cooling medium in the reduction PV panel temperature is to enhance the overall performance output. The increasing in temperature caused by heat generated will lead to the decrement power output of the PV panels. Therefore, heat generated must be removed in some way due to reduced the PV panel temperature. As the electrical power consumed by DC fan must be considered into account for the power input of PV panel, selecting the optimum number seems can be advantageously in terms of energy saving. The selection of the number DC fan mainly depends on the several factors such as atmospheric condition, speed and airflow DC fan used as well as size of the PV panel. Furthermore, the installation cost of cooling mechanism for PV panel can be reduced with minimized the number of DC fan. The existing cooling mechanism makes possible to pretend PV panel temperature reach at which irreversible damage occurs, even under peak solar radiation of multiple suns.

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REFERENCES

Burke, M., 2004. Why and how to control fan speed for cooling electronic equipment. Analog Dialog, 38: 1-3.

Farhana, Z., Y.M. Irwan, R.M.N. Azimmi, A.R.N. Razliana and N. Gomesh, 2012. Experimental investigation of photovoltaic modules cooling system. Proceeding of the 2012 IEEE Symposium on Computers and Informatics, 18-20 March, 2012, IEEE, Kangar, Malaysia, ISBN:978-1-4673-1686-6, pp: 165-169.

Hernandez, M.R., G.J.R. Cascales, V.F. Garcia, A.S. Kaiser and B. Zamora, 2013. Improving the electrical parameters of a photovoltaic panel by means of an induced or forced air stream. Int. J. Photoenergy, 2013: 1-10.

Irwan, Y.M., A.R. Amelia, M. Irwanto, M. Fareq and W.Z. Leow *et al*., 2015. Potential of solar radiation and ambient temperature as an alternative energy in perlis. Appl. Mech. Mater., 793: 323-327.

Irwanto, M., N. Gomesh, M.R. Mamat and Y.M. Yusoff, 2014. Assessment of wind power generation potential in Perlis, Malaysia. Renewable Sustainable Energy Rev., 38: 296-308.

Onur, N., 1993. Forced convection heat transfer from a flat-plate model collector on roof of a model house. Heat Trans. Substances, 28: 141-145.

Teo, H.G., P.S. Lee and M.N.A. Hawlader, 2012. An active cooling system for photovoltaic modules. Appl. Energy, 90: 309-315.

Wilson, M.J. and M.C. Paul, 2011. Effect of mounting geometry on convection occurring under a photovoltaic panel and the corresponding efficiency using CFD. Solar Energy, 85: 2540-2550.

Zhang, X., J. Shen, P. Xu, X. Zhao and Y. Xu, 2014. Socio-economic performance of a novel solar photovoltaic loop-heat-pipe heat pump water heating system in three different climatic regions. Appl. Energy, 135: 20-34.

Zogou, O. and H. Stapountzis, 2011. Experimental validation of an improved concept of building integrated photovoltaic panels. Renewable Energy, 36: 3488-3498.