The Effect of Surface Water on The Performance of PV Module

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Abstract— **Lifespan of photovoltaic cells is estimated around 20-25 years. The rate of degradation will increase rapidly if the temperature goes beyond the certain limit. The increase of working temperature of photovoltaic (PV) cell through absorption solar radiation is inversely proportional to the electrical efficiency. With the purpose of increase the PV efficiency, it is crucial to keep the PV cell temperature at minimum level. This paper introduces the probability of increasing the performance in terms of output power and efficiency using passes running water on the surface of PV module. Results gained from this method are compared with the unaltered PV module. The results show that it manage to bring down the operating temperature of PV module but the water itself interfere with the solar absorption and dropped the efficiency of the PV module. All the data was recorded using solar module analyzer (PROVA 200) and from the short circuit current of module shows that the electrical performance is worsen.**

***Keywords-** PV modules; I-V curve; Temperature; Passes running water; Efficiency; Performance*

I. INTRODUCTION

Fossil fuels contribute large amount of energy generation nowadays. Environment is affected greatly by fossil fuels and it cannot be renewed. In order to cope with this situation, renewable energy was introduced. Currently, renewable energy supply somewhere between 15 percent and 20 percent of world's total energy demand [1]. Solar energy provides another option for generation of electrical energy although it has pro and cons but it gives great contribution to the environment. One of the commonly known types of renewable energy is solar energy. Solar energy is being use all over the world and main to the development of renewable energy [2]. The development of solar technology is expanding rapidly and extensive research currently has been made so that utilization of the energy is more efficient.

In photovoltaic (PV) systems, the main obstacles are the low energy efficiency and high initial cost. The changes of temperature tend to result the electrical efficiency of PV solar module and reduce the module's open circuit voltage due to decrease in temperature [3]. Extreme solar radiation and high surrounding temperature causing PV to overheat which radically reduce the efficiency [1]. Rodrigues et al. states that "temperature change between 0°C and 75°C of an ideal P-V characteristic of solar cell shown in Fig. 1" [1]. The characteristics give an idea about relationship between output power, P and output voltage, V while solar irradiance, G and module temperature, T is unchanged. The entire characteristics will change if one of the factors, G and T change [4]. The output power, P radically affected by the heating of PV panel

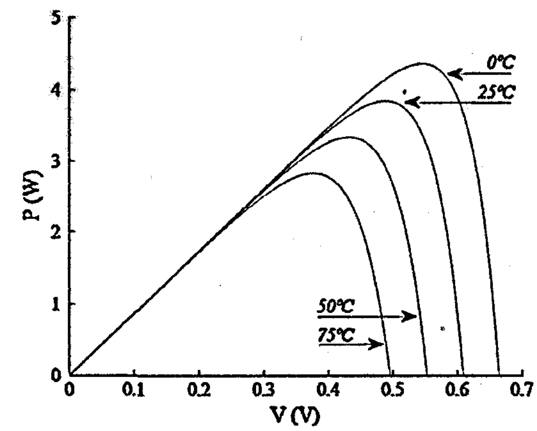


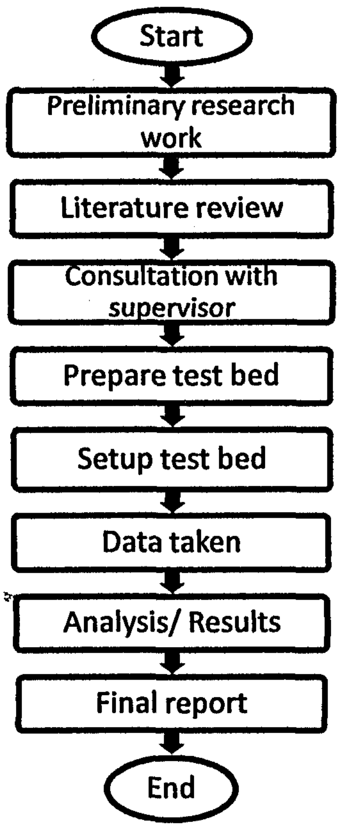
Figure 1: P–V characteristics. The module temperature varies between 0 °C and 75 °C.

In order to reduce the module temperature, T, this research use passes running water on the surface of PV. It works as coolant to increase the output power, P, so the efficiency can be increased. Major concern by using this technique is running water may partially or totally block the PV module itself thus reduce concentrating light or solar spectrum from entering PV module. Concentrating light requires direct sunlight and diffuse light possibly will happen when passes running water applied to the PV module.

The main purpose of this work is to study effect on decreasing module temperature and PV reflection when passes running water apply on surface of PV module. In addition, result of decreasing module temperature can improve the performance of PV in terms of output power generated by module and efficiency respectively.

II. METHODOOGY

An experimental setup was conducted to investigate the effect of surface water on the performance of PV module. The photovoltaic system used in this research consists of 2 PV Mono-crystalline modules (SPM050-M) with efficiency of 16% and a water pump 18W (1.5m maximum head and 1400(L/H) maximum flow rate). Solar module analyzer (PROVA 200) is used to capture IV curve characteristics, max current (Imaxp), max voltage (Vmaxp) and max power (Pmax). Fig 2 shows the test setup. The data sheet of PV module is shown in Table 1.



Flowchart of the project

A) *PV Module Efficiency*

The maximum power can be generated by the presence of maximum current, Imax and maximum voltage, Vmax. Equation (5) to (7) taken from [10] shows that:

$$Pm = Vm \times Im = FF(Voc \times Isc) \tag{1}$$

FF indicates the fill factor can be determined by:

$$FF = \frac{Imp \times Vmp}{Isc \times Voc} \tag{2}$$

From the fill factor calculated, it can suit the efficiency formula:

$$\eta = \frac{P_{out}}{P_{in}} = \frac{I_{mp} \times V_{mp}}{G \times A} = \frac{I_{sc}V_{oc} \times FF}{G \times A} \tag{3}$$

Where:

G = Solar irradiance (W/m2)

A = Area of PV module (m2)

FF = Fill factor

B) *Maximum Power, Voltage and Current*

The maximum power can be calculated using quation (8). %γpmp obtained in PV module datasheet which value is -0.45 ± 0.05 (%/°C) while Gstc as 1000 (W/m2) and Tstc is 25°C. Value T cell_effective measured by thermometer which is module temperature. Equation (8) to (10) taken from [10] shows that:

$$P_{mp} = P_{mp_{stc}}(1 + \left[\left(\frac{\%\gamma_{pmp}}{100}\right) \times \left(T_{cell_{effetive}} - T_{stc}\right)\right] \times \frac{G}{G_{stc}} \tag{1}$$

Value of V_{oc} and I_{sc} calculated using equation (9) and (10) respectively. The value of %γvoc is given as -0.45 ± 0.05 (%/°C) use same as %γpmp.

$$V_{oc} = V_{oc\_stc}(1 + \left[\left(\frac{\%\gamma_{voc}}{100}\right) \times \left(T_{cell\_effetive} - T_{stc}\right)\right] \tag{2}$$

$$I_{sc\_corrected} = I_{sc\_stc} \times S_f \times F_{dirt} \times F_{mm} \quad (3)$$

Where

S_f $= \frac{G}{G_{stc}}$ = Solar fraction (p.u)
F_{temp} $= 1 + [(\frac{\%\gamma_{pmp}}{100}) \times (T_{cell\_effective} - T_{stc})]$
F_{mm} = module mis-match (p.u)
F_{dirt} = dirt factor (p.u)
G = Solar irradiance (W/m^2)
T = Temperature (^0C or ^0K)

C) *PREPARATION EQUIPMENT, TOOLS AND FACILITIES*

The test setup was conducted at Green Energy Research Centre (GERC), UiTM Shah Alam. 18W water pump is being used to pump water from the water container. Pump was connected to a water spray part through hose pipe. Tube with small holes placed on top of PV module to spray water over the module. The irradiance changes during test day is shown in Fig.3 and the module temperature measured by IR thermometer for every half an hour from 9.00 a.m to 5.00 p.m.

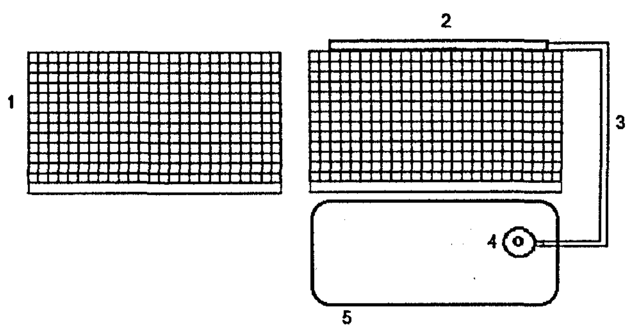


Fig 2: Photovoltaic with wate spray system

The test setup is shown in Fig. 2 that consists of:

1. 2 PV modules 50W.
2. Water spray part.
3. Hose pipe.
4. Water pump 18W.
5. Water container.

Water from the container sucked by pump through hose pipe that connected along the PV module. The water pump channel water until it reach on top of PV module. The water then enter the spray part where small holes allow water to flow on the PV module surface. Water then flow until enter the container once again and it is a water cycle system.

Table 1: Electrical characteristics of PV module

Electrical characteristics	
Model no.	SPM050-M
Power rating (Pmp)	50W
Open circuit voltage (Voc)	22.53 V
Short circuit current (Isc)	2.97 A
Voltage at maximum power (Vmp)	18.68 V
Current at maximum power (Imp)	2.77 A
Nominal voltage	12 V
Panel efficiency	14.67%
Maximum system voltage (Vmax)	1000 V
Maximum series fuse rating	10 A
Cell type	Monocrystalline silicon
Cell size (mm x mm)	125 x 125
No of cells per panel	36(4 x 9)
Panel dimensions (mm x mm x mm)	630 x 641 x 30
Weight	4.5 kg

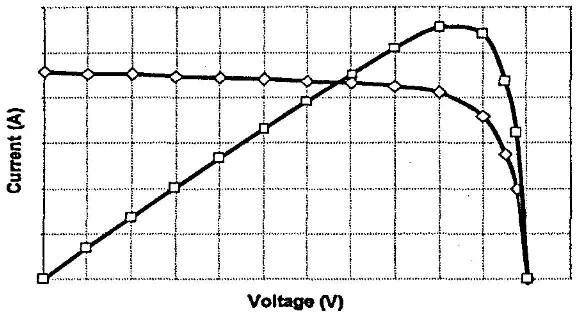


Fig. 3: I-V curve characteristics

One of the most important characteristics of PV modules is called I-V curve. The curve shows the possible combinations of current and voltage output of a photovoltaic (PV) module. The red curve is a current voltage curve, I-V curve whereas the purple curve is the maximum power, Pmax. If the I-V curve changes which is decline, it will affect the power curve also.

III. RESULTS & DISCUSSION

The main factos that affected usage of passes running water on PV module surface are the temperature decrease, maximum output produce and the efficiency of PV module.

A. Temperature reduction

The increase in temperature will give an opposite effecet on the PV module efficiency [6]. Since the electrical output and efficiency depend on operating temperature, it is essential to keep it low. Based on Fig. 5, temperature reduction is significantly visible between using water as coolant and untouched condition of PV module. There is huge difference in module temperatureWater applied on the surface successfully reduce the operating temperature which was measured simultaneously using PROVA 200.

Mono-crystalline PV module depends on the operating temperature to produce electrical power generation [6] consume by constant water flow from the water pump. This continuous water supply managed to reduce PV module temperature and should be increase the output power produce whereas it has decreased the output power produced.

Table 2: Electrical characteristics by PV module

		Without water		Water	
Time	Irradiance	Pmax	Temp.	Pmax	Temp.
9:00AM	111	6.12	29	5.2	29
9:30AM	146	7.84	30	6.9	29
10:00AM	240	12.34	33	11.7	30
10:30AM	456	18.76	38	18.37	31
11:00AM	526	40.72	44	29.48	33
11:30AM	724	38.92	50	36.7	38
12:00PM	875	38.56	55	34.81	42
12:30PM	900	38.66	58	33.28	45
1:00 PM	870	39.4	58	38.24	38
1:30 PM	860	37.28	60	26.17	46
2:00 PM	790	33.15	56	24.06	39
2:30 PM	770	32.36	56	25.57	41
3:00 PM	670	29.52	54	23.4	40
3:30 PM	510	23.42	47	18.17	39
4:00 PM	460	16.31	43	18.03	38
4:30 PM	500	19	43	17.56	33
5:00 PM	300	16.17	31	16.75	26

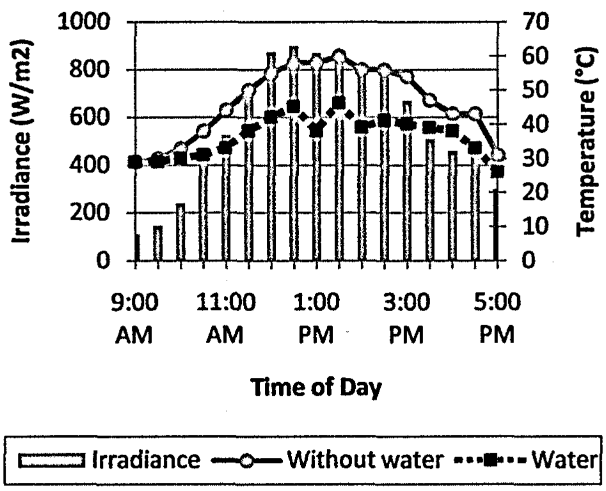


Fig. 4: Temperature reduction on PV module

B. Decrease in electrical output power and efficiency

Based on the reduction of temperature of PV module, the temperature has managed to be lowered down. On the other hand, the efficiency and output power produced has shown decrement shown in Fig.6 and Fig.7 respectively. The water that works as coolant is the main problem that cause decrement in output power produced and efficiency. Based on previous studies by M. Ameri [7] the reduction of temperature will increase the electrical performance of PV module. There are many factors that contribute to this condition as the main factor is the usage of water. It has block either partially or totally the surface of PV module and cause solar irradiance cannot hit directly to the surface. It may has dispersed or diffused the solar irradiance. The water should be separated evenly on the surface of PV module. The uneven water contribute to the reduction of module temperature but reduce the electrical performance of it. In Table 2 shows the difference value in temperature and maximum output power produced between using water and without using water on surface of PV module.

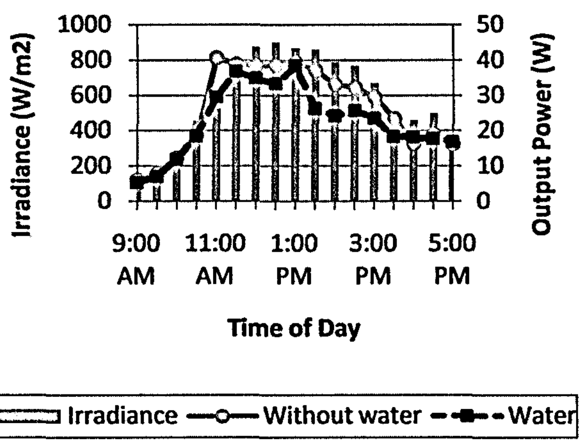


Fig. 5: Output power produced by PV module between 2 condition

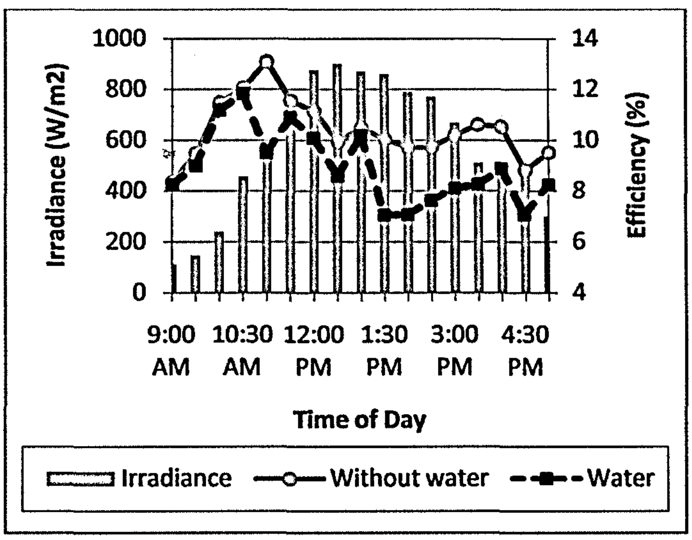


Fig. 6: Effeicency of PV module between 2 condition

The efficiency is calculated as:

$$\eta = \frac{Pout}{Pin} = \frac{Pout}{G\,x\,A}\ x\,100$$

η = Efficiency (%)

G = Solar irradiance (W/m^2)

A = Area of PV module (m^2)

IV. CONCLUSION

High increase in operating temperature of PV module give a great impact on PV electrical performance which lower its output power and effciency. In order to deal with this matter, it is essential to keep the PV module temperature low so it can produce highest output power. Increas in temperature of PV can be lowered using passes running water on the surface of PV module during the day. The results show the effect of surface water on electrical performance of PV module. Usage of water in this method is very successful to reduce the PV module temperature. The significant different in temperature is visible in Fig. 4 and comparison between has been made using water and without using water.

On contrary, the usage of passes running water on surface PV module has lowered its capability to produce maximum power. Water has created some sort of barrier that blocked the solar irradiance thus reduce its efficiency in Fig 6. Although using water as coolant is greatly reduce temperature but it reduced the effciency produced by PV module. This method is not recommended to use as it gives disadvantages in producing maximum power output and the implementation should be improved. At the end of this project, the relationship between effect of temperature to the output power can be determined but it is affected by water

The recommendation for this project is to use blower instead of water to cool down temperature of PV module. Air blower should be placed near the PV module because air blower so that PV module can get the maximum solar irradiance unlike water that create thin layer of barrier that block the PV surface. Apart from that, it is also suggested to use air duct at the bottom of PV modules. The air duct works same as car radiator and use liquid coolant. When coolant is heated, the heat lost to atmosphere through air duct.

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