Preliminary Study of Solar PV Characteristics Cooled by Water Spray

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Abstract: The efficiency of the solar PV array will decrease significantly as the temperature of the surface module exceeds a certain limit a nominal value. To handle the efficiency problem, it is important to control the surface temperature of solar PV. This study investigated the effect of the surface temperature of solar PV array modules due to automatic water spray cooling installed on the top roof of a residential structure in the Denpasar area. The performance indicator were then compared to that of the case without a water spraying cooling system. A thermostat is an automatic controlling system of cooling mechanism to keep the surface of solar PV temperature nearly to the ambient temperature. In this experiment, the surface temperature was kept at approximately around 33^{0}C with the active cooling system by the water spraying technique focus on the front surface of the PV module. The result presented an increase of PV voltage by 4.69% on average. Consequently, the output power produced by the cooled PV array module increase is 107.14 W against 94.01 W for the non-cooled PV array.

1 INTRODUCTION

To limit the use of fossil fuels and reduce the carbon footprint of the global electricity system requires comprehensive policies on production and incentives to stimulate growth in renewable energy use. Electricity generation from solar energy resources which is utilizing solar radiation with solar panels as alternative energy offers many advantages namely cheap, pollutant-free, and environmentally friendly energy. Solar PV is a very promising energy instrument for the sustainability of energy development (Jager-Waldau, 2019; Meral et al. 2011). Power generated by solar energy is a function of the PV module efficiency, and several other factors i.e., cell materials, photovoltaic system devices, environmental factors. Special attention is paid to environmental factors, hot climatic conditions, long periods of sunshine, and high ambient temperatures which is given a very dominant factor influence on

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the efficiency and power of PV module. With environmental conditions as described above, there is a reduction in the quantity of energy that is converted into useful energy by about 31%. The rest of it will be changed into heat energy which will affect the surface temperature of the PV panel. This condition will decrease the PV module lifespan and energy conversion efficiency (Idoko et al., 2018).

Several introductory articles regarding the solar PV cooling method as a solution to the overheating of PV surface temperatures describe below. It is well recognized that the number of efficiency can be reached by keeping the surface panel temperature. (Moharram et al., 2013) the investigation was made to reveal the phenomena of cooling the PV module using water spraying, this study also revealed how long to decrease the temperature of the surface temperature to 35^0C. From the data, it specifies the PV energy output was highest when surface temperature commenced around 45^0C. In the study by (Schiro et al., 2017), for controlling the temperature and reaching the maximum module performance, the researcher studied the opportunity of a cooling system method without varying the original PV structure. They observed the specified methods to maintain the temperature of the front panel with watering. The result shows, the method applied in this experiment could recover both the economic and performance aspect of the PV system. (Sajjad et al. 2019) expected to increase the efficiency and performance. A special cooling system developed by placing PV modules in the refrigerated duct of a buildings. The performance was made for one PV module cooled by refrigerated air and the other one was non-cooled. The cooled PV performance reaches 6% higher compared to that of the without cooling system. Also, the efficiency reached 7.2% better. In another research an investigation of applied water as cooling medium by (Abdolzadeh and Ameri, 2009). The aims of the study were to decrease the PV module surface temperature. In the case of spraying, it is usual use a water pump. The experiment data shows a significant electrical power increase of the solar PV. Off course this phenomenon will causes the efficiency of the system better. An investigation by (Kordzadeh, 2010), a thin water film layer generated by spraying water at surface area of PV to reduce the PV array temperature. In this test rig, the pump flows the cooling water to the surface of PV module. The results confirmed that the improvement of PV module efficiency.

To increase the efficiency of the PV module array, another active cooling was preserve using a heat exchanger. (Ceylan et al., 2014) an approach was agreed out to deliver active cooling using a spiral heat exchanger. The HX was stationed on the module. The result designates 13% module efficiency increased with this HX cooling approach. A HX use as a precool the ambient air. This is an alternative cooling system employs. This method is used to cool the back surface of a PV panel. A good agreement was found to decrease the temperature from 55^0C to 42^0C (Elminshawy et al., 2019). Another active cooling method that is applicate from the back surface of PV modules using HX proposed by (Bahaidarah et al. 2013). The result found 9% of efficiency. This method assisted to decrease the module temperature significantly. For residential PV, another alternative cooling system method was proposed using channels which is placed under the flat of solar panel. In this schema, the thermal power exchanging take place between water circulation in/out from a tank for domestic hot water applications in England by (Peng, 2017). (Irwan et al. 2013) proposed a cooling system with the force convection system applied using a fan for air cooling. A good agreement on the amount of energy saving was accomplished. Another progress in fan cooling to reduce the temperature of PV modules by (Teo et al. 2012). In this experiment, the back side of the PV panel was tailored with an arrangement of air channel and found around 14% efficiency.

It can be summarized from the literature study done by many researchers that using water as a cooling media, found to be effective to increase the solar PV power. Therefore, the objective of this study is to build a cooling system using the spraying technique to controlled the surface of solar cells temperature from overheating problematic.

2 EXPERIMENTAL METHODS

A water tank with a capacity of 120L is considered to provide a supply cooling system of a PV panel (Figure 1). Water is pumped through the pipe system by a centrifugal pump. Ten nozzles were placed on the edge of solar PV which is spraying the water to the surface of solar PV. The solar PV was cooled during the optimum solar irradiance intensity of a day period of 2.5 hours, from 11:00 a.m. to 01:30 p.m., in May 2021 at Denpasar city, Bali, Indonesia. The experimental setup comprises two solar PV units. Every solar PV unit has 72 monocrystalline silicon cells. The load is about 50 W. The unit's specification is presented in Table 1.

Table 1: Spesification of the PV panel.

Parameter of PV panel	Spesification
Cell type	Monocrystalline Si
Number of cells	72
Maximum power (Pmax)	220 W
Current at P max/ Isc	5.73A
Voltage at P max/ Voc	47.00V
Dimensions of module (mm)	1320 x 992 x 40

The graphic of the test experimental setup is shown in Fig.1.

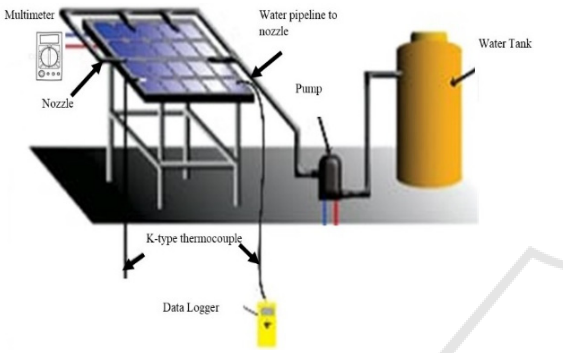

Figure 1: Sketch of water spray cooling system of the solar PV.

The PV panel is placed at a proclivity angle around 15^0 to the flat surface. The positioning of solar PV depends on geographical conditions. Besides that in the meantime of spraying, this inclination will prevent puddles on the surface of solar PV. The experiments were carried out for cut-off surface temperature around 33^0C. Temperature measurements were taken every second from some point in the surface of the PV module with K-type thermocouples and logged with a data logger. Meanwhile, electrical parameters were taken via Bluetooth communication for every 30 s.

3 RESULT AND DISCUSSION

Firstly, the data were conducted under relatively high radiation intensities at noon. The increase of PV-surface temperature was logged under these solar irradiances without any cooling system. The data was then compared to that of the surface temperature of solar PV 33^0C. The water flow rate considered for the spray cooling is 4 l/min of all PV surface area.

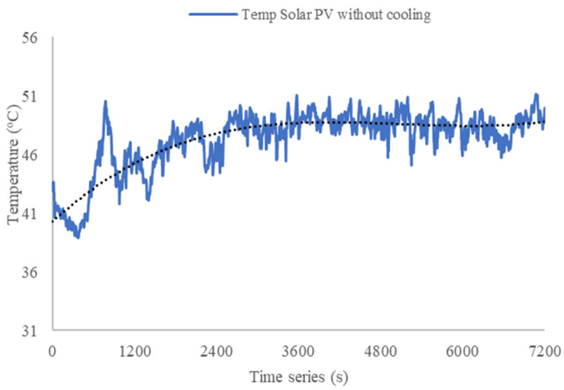

Figure 2: The time series of PV surface temperature (for without-cooled).

Figure 2 shows the temperature of the PV surface as a function of time. It can be seen, that the temperature increased gradually by increased of time. The temperature of the PV panel surface for the uncooled PV system is varied and reached a maximum of about 51.5^0C. The panel cooled down by the spray water cooling systems and maintain the surface temperature around 33^0C with a deviation of about 2^0C as shown in Fig 3.

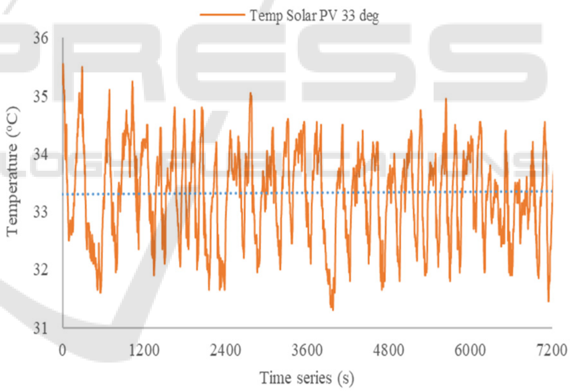

Figure 3: The time series of PV surface temperature (for 33^0C conditions).

The spray technique is effective to reduce the PV surface temperature by reducing the reflection of electromagnetic radiations and the efficiency of solar PV are strongly correlated with the solar spectrums. (Hadipour, 2021). Fig. 4 shows the time series of voltage values of the duty cycle on the experiment period. As shown in fig.4, by decreasing the surface temperature of PV, the voltage produced by the solar PV increase.

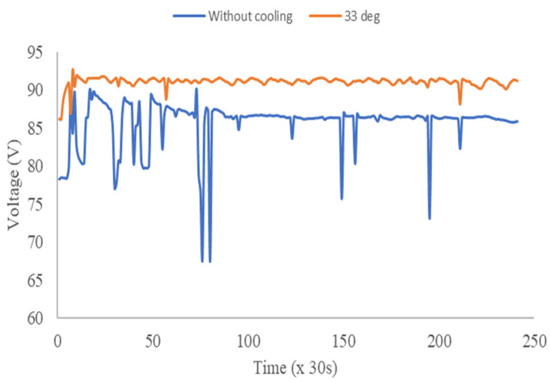

Figure 4: The time series of PV voltage (for without-cooled and 33^{0}C conditions).

The maximum electrical voltage significantly increases, by decreasing the surface solar PV temperature. The changes in the maximum current of the PV panel can be observed in Fig.5. It is also revealed, the water spraying cooling technique is more effective to increase the current in a high solar irradiation environment.

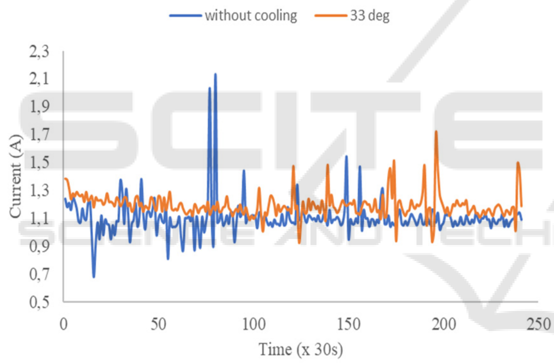

Figure 5: The time series of PV current (for without-cooled and 33^{0}C conditions).

Fig. 6 described the time series of the electrical power generated by solar PV for all variables in this research. As described in this figure, the average electrical power output of 94.01 W. On the other hand, the average electrical power output is 107.29 W for the cooled PV panel can be achieved by using a steady water spraying cooling system. The more decreases of the surface PV temperature, the more increases power output.

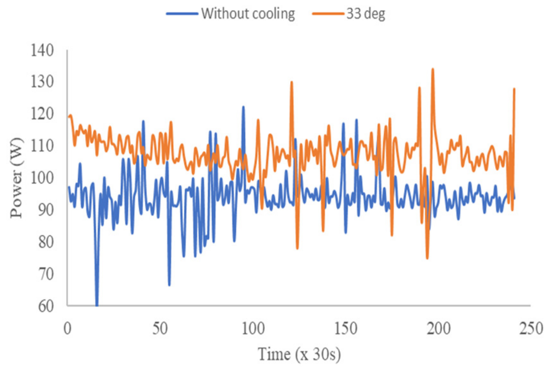

Figure 6: The time series of PV power (for without-cooled and 33^{0}C conditions).

The spray cooling technique has the better performance on the electrical parameter but they're still need to investigate about the electrical efficiencies for both cases. So, it is strongly suggested to use the water spraying technique for maintaining the PV panel's temperature.

4 CONCLUSIONS

To cool the PV panels, this research proposed a technique using spray water. The experimental setup has been arranged to find the correlation of cooling the PV surface on the electrical parameter. It can be determined from the results that:

1. The application of a cooling system by means of spray cooling is very possible.
2. Based on the concern operating conditions the average power for cooled PV surface is 107.29 W, and 94.01 W for non-cooled PV surface. It has a strong correlation between the output electrical energy and surface PV temperature.

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