AMERICAN JOURNAL OF AGRICULTURAL SCIENCE, ENGINEERING, AND TECHNOLOGY (AJASET)

ISSN: 2158-8104 (ONLINE), 2164-0920 (PRINT)

VOLUME 6 ISSUE 3 (2022)







PUBLISHED BY: E-PALLI, DELAWARE, USA

American Journal of Agricultural Science, Engineering, and Technology (AJASET)

Volume 6 Issue 3, Year 2022
ISSN: 2158-8104 (Online), 2164-0920 (Print)
DOI: https://doi.org/10.54536/ajaset.v6i3.919
https://journals.e-palli.com/home/index.php/ajaset

Effect of Spray Angle and Flow Rate on Improving PV Panel Performance: Experimental and Theoretical Study

Qusay Kamil Jasim[1*]

Article Information

Received: November 10, 2022

Accepted: November 20, 2022

Published: November 29, 2022

Keywords

Spray- Cooling, Solar-Panels, Spray-Angle, Nozzles, Pulsating Water-Spray

ABSTRACT

A spray cooling system is used to improve the efficiency of solar cells discussed in this article. Cooling of solar panels is a significant factor that affects their performance. This experiment explores the effects of spray angle, nozzle to PV cell distance, nozzle number, on panel performance. A test rig was created for this purpose. The spray angles ranged from (10 to 45 %). When the spray angle is reduced to 20°, the electrical efficiency of the PV panel climbs to 18.763 percent, while the average PV panel temperature drops from 60 to 26 degrees Celsius (for non-cooled PV). Additionally, the distance between the nozzle and the PV panel was increased from 10 to 55 centimeters. With a 24.45% increase in power production, the best result was reached for the shortest distance. The results of the water spray system show that the greatest effici-ency was reached.

INTRODUCTION

In Iraq, most of energy sources depend on fossil fuel (oil and gas) sources. Less than 5% of produced energy is contributed from renewable energy. Due solar systems' ability to function in various environments, many assessments of their behavior have been conducted; the findings have revealed that only 15% of solar sun can be converted to electricity, with the remainder being lost as heat (Teo *et al*, 2012). Because the efficiency of photovoltaic solar cells drops as the temperature rises (Dubey *et al*, 2013), cooling them is necessary to improve performance. For solar cells, this leads in a 0.4 percent /°C loss in electrical power output and a 0.5 percent /°C reduction in electrical yield. Electrical efficiency in solar systems may often be rise by lowering module temperature.

Furthermore, several cooling systems that use water as a coolant have been examined in (Abdolzadeh *et al*, 2009) and (Zhu *et al*, 2014), with a 10–20 percent rise in output power attained. In addition to the cooling solutions mentioned above, hybrid PV-other-mal energy systems can improve total PV module efficiency. Many experimental and numerical investigations have been conducted to increase the performance of PV modules. (Neyer *et al*, 2014) & (Chandrasekar *et al*, 2014) and (Nada *et al*, 2018) are a few examples.

This paper describes a newly built experimental setup for analyzing the effect of water spraying on PV panel performance when the front side of the panel is cooled. Two elements were altered to get the best electrical efficiency and output. To minimize water usage during the cooling process, the number of nozzles has been reduced. The research aims to use the best water spray cooling approach to improve the solar system's electrical efficiency. According to the literature assessment, rising solar system efficiency is linked to increased water use. In this article, a fresh attempt was made to improve the solar panel's electrical efficiency while lowering water use.

METHODOLOGY

Experimental Rig

The experimental setup was created to analyze the influence of water cooling on the performance of a PV panel. Experiments were conducted to examine how cooling affects the PV system's performance. As seen in Figure 1. An 250W PV panel with an effective surface of 1.64 m2 was used to create a particular system. Table 1 lists the properties of the module.

The pipe and its nozzles are designed uniquely to prevent shadowing. With PV panels, shade is a major concern, as shading just one cell can drastically lower output power. The sun irradiation was measured during the tests using an SPM-1116SD pyrometer. A MIT-367 infrared thermos-meter with a 2°C precision, a digital thermos-meter and a flow rate meter were also included in the system.



Figure 1: Experimental Rig with all parts

[1] Power Mechanics Techniques, Northern Technical University, Kirkuk, Iraq
[*] Corresponding author's e-mail: qusay_hwj@ntu.edu.iq

Table 1: Properties of PV Panel

Parameter	Specification		
Power	250W	Co-eff. Power Pm	-0.4% /^{0}K
Open circuit Voltage	37.74V	Co-eff. Voltage Voc	-0.34% /^{0}K
Short circuit Current	8.74A	Co-eff. Current Isc	+0.005% /^{0}K
Voltage at maximum Power	30.5V	Weight	18.0Kg
Current at maximum Power	8.2A	Dimension	16.45 x 9.92 x 4.2 cm

Measurements Device

A data-logger was used to record the voltage and temperature of solar panels automatically. Four sensors (Copper constantan thermocouples) were fixed on the surface panel to measure its surface temperature. On the other hand, they connected to the logger and adjusted frequently to record data. To connect data logger with PV modules, two resistances were connected between Logger and modules to decrease the volt. On the other side the logger was connected with PC using USB cable as shown in the schematic diagram in Figure (2). The logger operates with low voltage-less than 5 V, so according to the manual of the logger, the resistances Rs and Rsp were used to adjust the voltage, VPV of logger and the diode was used to protect the circuit. The value of voltage VPV was calculated using the following Equations:

$$\frac{V_1}{R_S} = \frac{V_{PV}}{R_{SP}} \quad \ldots (1)$$

$$V = V_1 + V_{PV} \quad \ldots (2)$$

$$V_{PV} = V_1\left(\frac{R_{SP}}{R_S}\right) \quad \ldots (3)$$

Where: RS and RSP are series and parallel resistance (Ohm)respectively.

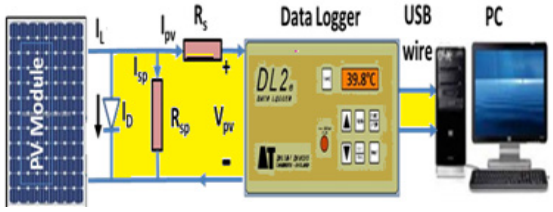


Figure 2: Schematic diagram shows data logger with computer and PV panels.

Measurement Error Analysis

The estimated measure-ment error for the measuring equipment is mentioned in this section. See table 2. Table 2 shows the measurement inaccuracy of each piece of equipment.

Table 2: Shows the measurement inaccuracy of each piece of equipment

Measuring Name	Error (%)
Ampere-meter	±2
Pyrano-meter	±5
Volt-meter	±0.5

The electrical efficiency is calculated using the equation for Propagation of Error (Popovich *et al*, 2016).

$$\eta = \frac{I.V}{E.A} \quad (4)$$

where V: max. voltage, I: max. current, E: is the pyrometer-measured solar irradiance, and A: constant module effective area (Yun *et al*, 2007).

$$S_\eta^2 = \left(\frac{\delta\eta}{\delta V}\right)^2 s_v + \left(\frac{\delta\eta}{\delta V}\right)^2 s_v + \left(\frac{\delta\eta}{\delta V}\right)^2 s_v \quad (5)$$

V, I, and E are derivatives of each variable.

$$\left(\frac{\delta\eta}{\delta V}\right)^2 = \left(\frac{I}{E}\right)^2 \quad (6)$$

$$\left(\frac{\delta\eta}{\delta I}\right)^2 = \left(\frac{V}{E}\right)^2 \quad (7)$$

$$\left(\frac{\delta\eta}{\delta E}\right)^2 = \left(-\frac{IV}{E^2}\right)^2 \quad (8)$$

Analytical Model

Water spray cooling is more effective than other ways of water cooling for PV modules. Water spray cooling's cleaning role is vital in eliminating dust from various solar power plants, in addition to providing effective heat transmission. As a result, spray cooling all components of the PV module has the primary purpose of maximizing heat loss to the environment while decreasing surface temperatures to increase electric power production. The heat input into the surface is (Du *et al*, 2013).

$$Q_{solar} = \alpha .E.A_m \quad (9)$$

where α : absorptivity coefficient. (QC), (QR) and(QE) Convection ,radiation and evaporative heat loss all contribute to the total heat loss (Qloss) in this test. Eq. 10 may be used to compute overall PV module heat loss, which includes the all loss indicated above:

$$Q_{loss} = Qc + QR + QE \quad (10)$$

The loss convection in a PV panel may be estimated as (Harry *et al*, 2O21):

$$Qc = QC,F + QC,B \quad (11)$$

Where

$$QC,B = h_{back}\, Am(T_{module}\, back - T_{air\ back} \quad (12)$$

$$QC,F = h_{front}.Am(T_{module}\, front - T_{airfront}) \quad (13)$$

Total radiation heat loss is estimated using Eq. 14,

$$QR = Q\,R,F + Q\,R,B \quad (14)$$

where radiation heat loss is determined using (Singh, 2O20)

$$QR = \sigma Am.F12\,(T^4 1 - T^4 2) \quad (15)$$

Both sides of the module may be determined using Equation 15.

RESULTS AND DISCUSSION

Solar Irradiation

In Iraq, the spray cooling test was applied. The temperature in the surrounding region ranged from 30 to 40 degrees Celsius during the testing. All of the trials were carried out in July to obtain the best and maximum irradiation.

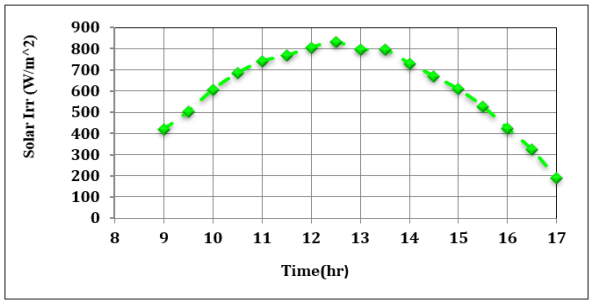


Figure 6: Solar irradiation intensity with time

Figure 6 depicts the pyrometer's measurement of solar irradiation intensity on one of the July experiment days. They varied from 200 to 830W/m^2.

Effect water spray cooling system

The working PV panel temperature was reduced because evaporation and the cool-ing impact of water spraying. The ambient and water temperatures were 30 to 40 degrees Celsius and 16.5 degrees Celsius, respectively. The highest PV temperature occurs for the non-cooled - panel, as illustrated in Figures 7 and 8, and it is 64°C (average of observed surface temperature) before and after cooling, as measured by an infrared thermometer. Different portions of the PV panel's front surface were measured, but the average quantity is shown in the graphs below. Cooling resulted in a 40-degree drop in temperature.

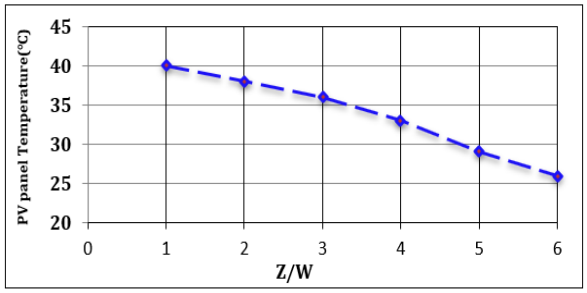


Figure 7: Panel temperature with Z/W with cooling

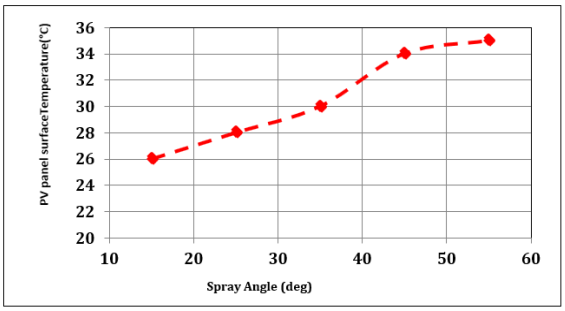


Figure 8: Panel Temperature with Spray Angles at Cooling

The influence of nozzles on the spacing between PV panels on performance

The distance between the nozzles and the PV panel is one of the parameters that affects the efficiency of the solar panel. The distance between the nozzles and the PV panel (Z) was changed between 10 and 50 cm in five different modes, as shown in Figure9.

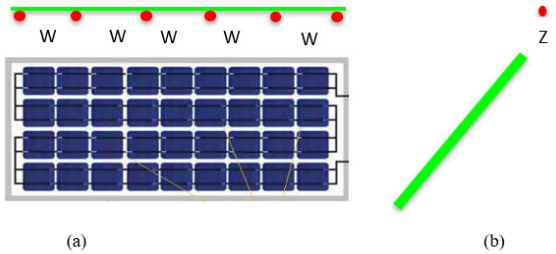


Figure 9: a The distance between each nozzle (W) and b The nozzles distance (Z)

Efficiency reduced from 12.83 to 11.34 percent by increasing (Z/W) from 0.9 to 5. The highest electrical efficiency was achieved at the shortest distance between the nozzles and the panel. With a (Z/W) of 0.9, max. increase in power was 14.93 W. While the biggest improvement in efficiency was 25.86 percent, the highest of all the experiments in this research, with a (Z/W) of 0.9 when compared to non-cooled systems. In contrast to other sets of tests, this percentage represents the most significant gain. For the greatest distance from the panel (Z/W) = 5), the electrical efficiency increased the least. See Figure 10

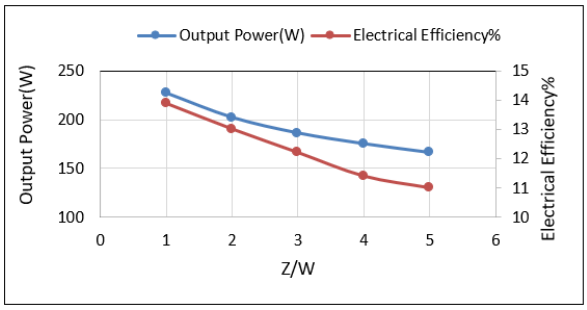


Figure 10: Nozzles distance with power & electrical efficiency

Effect Spray Angle on Performance

After cooling at a 20° angle, the highest power & efficiency were 78.09 W and 12.03 percent, respectively. Electrical

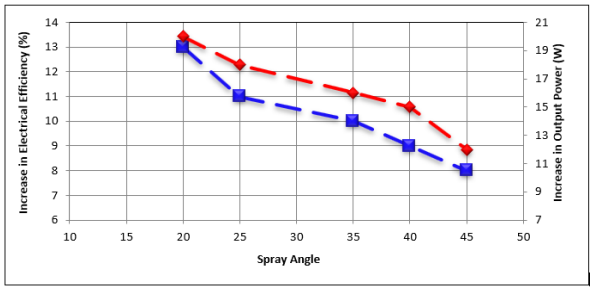


Figure: 11 Efficiency and power with spray angle

efficiency increased by 19.79 percent at a 20° angle. Electrical efficiency increased by 11.89 percent when the angle was changed to 30 degrees. After cooling the PV panel by 45°, the overall gain in electrical efficiency was 13.95 percent. In compared to the other five angles, the 50° angle of cooling exhibited the smallest gain in total efficiency -power after cooling. as shown in Figure 11.

Effect different number of nozzles on performance

Despite the fact that the water flow rate in this study was around 80 l/h, which is lower than other similar spray cooling methods in (Abdolzadeh *et al*, 2009) reducing the number of nozzles can also help to minimize water consumption and water flow rate. Because one of the most important parameters in heat transfer is water flow rate, increasing or decreasing the number of nozzles has an effect on the heat transfer coefficient and hence the heat transfer rate. Some of the nozzles were removed in this research to cut down on water usage. The cooling of water sprays in four different modes (9, 7, 5, and 3) was investigated. As shown in Figure 12.

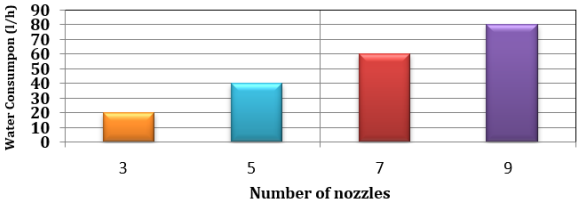


Figure 12: Water consumption for different number of nozzles

Because of the pressure loss at each nozzle, the rate of flow in varying numbers of nozzles is not proportionate. When compared to non-cooling mode, the efficiency and power rose 17.28 percent and 12 W, respectively, while the number of nozzles was reduced to nine. In addition, as compared to a non-cooled PV panel, the electrical efficiency of 7, 5, and 3 nozzles increased by 14 percent, 11.87 percent, and 9.2 percent, respectively. see Figure 13.

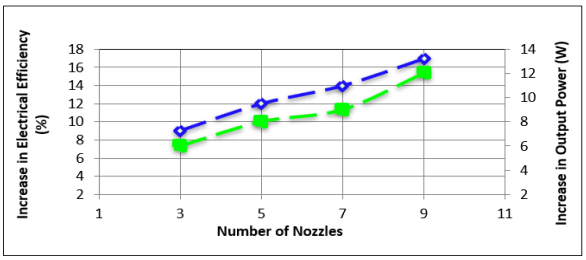


Figure 13: Efficiency and power of PV panel with nozzles

CONCLUSIONS

In this study, provide a new technique for improving the performance of PV panels. According to the study, water cooling increases panel performance. The outcomes of article support the idea that lowering cooling spray angle enhances efficiency and power. The lowest angle (20 degrees) produces the best outcomes compared to other perspectives. Furthermore, reducing the distance between the nozzles and the PV panel boosts efficiency and power. The Min. distance achieves the highest increase, according to the statistics. The water flow rate affects the electrical efficiency of a PV panel. According to the experiment's results, dropping the flow rate from 80 to 20 l/h reduces water use by 45 %. When compared to the steady state, the On–Off cooling system reduced water use while simultaneously lowering electrical efficiency and output power by roughly 10%. The highest gain in PV panel electrical efficiency relative to non-cooled mode was 24.22 percent, and it occurred at steady water cooling with Z/L= 0.9 at angle 20°, which are the nozzles to panel distance and angle, that are the lowest. Future study will focus on the water spraying system's economic approach.

REFERENCES

Abdolzadeh M, Ameri M (2009). *Improving the effectiveness of a photovoltaic water pumping system by spraying water over the front of photovoltaic cells*. Renew Energy.

Chandrasekar M, Suresh S, Senthilkumar T, Ganesh karthikeyan M (2013). Passive cooling of standalone flat PV module with cot- ton wick structures. *Energy Convers Manage, 71*, 43–50.

Du JD, Darkwa J, Kokogiannakis G (2013). Thermal manage-ment systems for Photovoltaics (PV) installations: a critical review. *Sol Energy, 97*, 238–254.

Dubey S, Sarvaiya JN, Seshadri B (2013). Temperature dependent Photovoltaic (PV) efficiency and its effect on PV production in the world—a review. *Energy Procedia 33*, 311–321.

Harry Ku (2021). Notes on the Use of Propagation of Error For- mulas. *J Res Natl Bureau Stand C Eng Instrum 70*(4), 263–273.

Neyer A, Drabiniok E (2014). Bionic micro porous evaporation foil for photovoltaic cell. *Microelectr Eng, 119*, 65–69.

Nada SA, El-Nagar DH, Hussein HMS (2018). Improving the ther- mal regulation and efficiency enhancement of PCM-Integrated PV modules using nano particles. *Energy Convers Manage, 166*, 735–743.

Popovici CG, Hudişteanu SV, Mateescu TD, Chereches N-C (2016). Efficiency improvement of photovoltaic panels by using air cooled heat sinks. *Energy Procedia 85*, 425–432.

Singh GK (2020). Solar power generation by PV technology: a review. *Energy, 53*, 1–13.

Teo HG, Lee PS, Hawlader MNA (2012). An active cooling system for photovoltaic modules. *Appl Energy 90*, 309–315.

Yun GY, McEvoy M, Steemers K (2007). Design and overall energy performance of a ventilated photovoltaic facade, *Sol Energy 81*, 383–394.

Zhu L, Raman A, Wang KX *et al* (2014). Radiative cooling of solar cells. *Optica 1*, 32–38.