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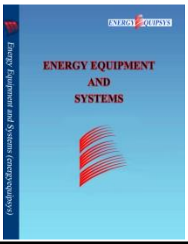

The assessment and experimental study of photovoltaics panel by spraying water (case study: Kerman, Iran)

Authors

Ali Pagodaripour [a]
Amir Ghasemkhani[b*]
Hossein Ghazizade-Ahsaee[a]
Amin Namjo[c]

[a] Department of Mechanical Engineering, Faculty of Shahid Chamran, Kerman Branch, Technical and Vocational University (TVU), Kerman, Iran

[b] Department of Mechanical Engineering, Faculty of Engineering, University of Sistan and Bluchestan, Zahedan, Iran

[c] Islamic Azad University-Kerman Branch, Kerman, Iran

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ABSTRACT

Today, utilizing renewable and clean sources of solar energy by solar systems is continuously increasing. Given that the output power of solar cells is dependent on radiation intensity, temperature, and voltage of the terminal, controlling their performance in order to maximum absorbed power has high importance. The high photovoltaic temperature in hot seasons leads to reduce panel power. Therefore, the water spraying on the photovoltaic panel was implemented on the photovoltaic panel. The effect of spraying water on the photovoltaic panel showed that spraying water on the panel during a warm day can significantly improve the panel's power. In this work, non-potable water (green space irrigation) has been used to cool and clean the photovoltaic panel. Reducing the price of photovoltaic systems by using fewer panels due to achieved of the panels to the more power is another significant advantage of spraying water on the photovoltaic panel. Results show that the efficiency of the experimented system increased by 20%.

Keywords: Renewable Energy, Photovoltaics System, Solar Energy.

1. Introduction

Varied periods of human civilization are based on discovering and utilizing different sources of energy; energy is the foundation of human life. That's why all the countries in the world are looking for energy sources**.** These resources strongly influence the country's industry, economy, and social life. The growing need for energy and the endurance of fossil fuels, on the one hand, and the increasing environmental pollution, on the other hand, have been prompted researchers and investors in the energy section to be absorbed to harness and secure renewable energy.

Renewable energies are continuous and permanent sources of energy because, unlike other fossil fuels, the risk of being exhausted is unexpected.

Renewable energies are more environmentally friendly. Fossil fuels emit significant amounts of pollutants into the Earth's atmosphere, while emissions of

* Corresponding author: Amir Ghasemkhani
Department of Mechanical Engineering, Faculty of Engineering, University of Sistan and Bluchestan, Zahedan, Iran
Email: a.ghasemkhani@pgs.usb.ac.ir

contaminants from renewable sources are absolutely low and sometimes close to zero. Overall, renewable energy has its advantages and disadvantages.

Thus, there are two ways to solve environmental pollution problems and energy analysis problems: 1-Finding new energy 2-Reducing energy consumption or optimizing the usage of resources [2]. One of the renewable and vital sources of solar energy. As you know, the energy that the Earth receives in one hour from the sun is more than the energy consumed by the world in one year. Iran, with latitude 25° to 45° Northerner, is in an appropriate area for energy. The amount of solar radiation in Iran is estimated to be between 1800 and 2200 kWh per hour, which is above the global average, and the average solar energy per day is 18 MJ / m^2. Photovoltaic technology directly and without The usage of chemical and propulsion mechanisms converts sunlight into electricity[1-5]. The generative power of solar silicon panels is depended on their operating temperature.

Increasing the panel temperature results in a slight increase in the short-circuit current of the panel and a significant decrease in the open-circuit voltage (2.3 mV/°C), and a reduction in the output power for the more common monocrystalline panels. Therefore, as the panel output power is influenced by the panel temperature, it is desirable to stabilize the panel temperature at low temperatures. In addition, the perpendicular collision radiation energy is lost due to surface reflectance of 4% to 5%. It is worth saying that in most applications, the angle between the panel and the collision beam is not perpendicular, so according to Fresnel's law, the reflection drop is higher[3]. The Reflective panel drop during a day depends on the angle of the ridge, the slope of the panel, the air filter coefficient, the surface behavior of the panel, and the coefficients of reflection of the layers adjacent to the panel. Using an optical model for a three-layer panel, the effects of different materials on radiation loss reduction have been researched. In this model, it has been shown that by using common materials in the structure of the panel layers, if standard materials are used in panel layout structure, under standardized conditions, the reflectance loss for panels in conventional panel (STC) systems will be between 8 % and 15 % and reaches 42% for tropical panels[6-27]. Using the aforementioned model, a three-layer panel consisting of panel windshield, anti-reflection coatings, and solar silicon cells, simulated. By changing the parameters of the model, we can get the following results:

1. Improved matching between the top two layers
2. Increase the passing light between the two layers by 3.2%

But the above research is possible if the materials for these two layers were chosen with reflectance coefficients of n_1=1.33, n_2=1.73; Unfortunately, it is not possible to achieve ideal materials with these specifications using solid materials, but in the meantime, water with a reflection coefficient of 1.3 has reduced the reflection drop by about 3%, resulting in a 3% increase in electrical power. There are other ways to reduce reflection, but they have disadvantages, for example, anti-reflective coatings can significantly affect this effect, but these materials are expensive and tend to absorb dust, making it difficult to clean the panel [5, 28-30].

Beygzadeh et al. analyzed thermodynamically and economically from a photovoltaic power generation system (PVEGS) with and without self-cleaning panels. Their purpose is to indicate the power generation's potential using conventional panels compared to self-cleaning panels under the same conditions. The results show that the solar photovoltaic system with self-cleaning panels has a higher performance than the solar photovoltaic system without self-cleaning panels available in all Iran climates [31]. More details on photovoltaic technologies in reference [31-38]. Previous research was carried out in 2011 to enhance the performance and power of experimental photovoltaic panels. In this experiment, the reflector was used to increase the radiation reaching the surface of the panel to increase the radiation, to increase the output power of the panel, but contrary to the notion, as the radiation reaching the surface of the panel, the temperature went too high (about 80 °C). This made the photovoltaic panel's production capacity less than desirable. [6] According to the Researches, increasing the temperature has an adverse effect on the efficiency of the photovoltaic panel. Therefore, cooling the panel can help increase efficiency. Improving the performance of the photovoltaic panel was studied experimentally. Water spraying will also reduce the reflection loss.

Abdolzadeh and et al. [32] examined the effect of water spraying on solar panels on the performance of photovoltaic water pumps. According to his report, this process increases the power of the panel and improves the performance of the panel.

Moharram and et al. [38] examined increasing the performance of photovoltaic panels by cooling water concluded that when the panel reaches its maximum temperature, the best time to cool the panel is to spray water every five minutes, which reduces the temperature of the panel by ten degrees and causes Increase electrical power، It was also proposed to optimize the cooling process and economic analysis.

This research solves the problems of previous research on water supply by integrating systems. The innovation of this research is the use of water spray to cool photovoltaic panels in the solar radiation peak using the control system. One of the problems of related research is the supply of water for cooling, in which water used to irrigate green spaces and plants to cool the panels has been used. In addition, this method cleans the panels with special Kerman weather conditions (dust in Kerman).

Nomenclature

T_a	Ambient temperature, K
$\dot{m}$	Mass flow rate, Kg/s
A	Area, m^2
G	Solar radiation rate, W/m^2
Greek letters	
η	Efficiency

2. Experimental setup description

To investigate the effect of water spraying on photovoltaic panels, two sets of photovoltaic panels were tested under the same conditions at the Islamic Azad University of Kerman. The results of the experiments were recorded on two sets, one with water spray and the other without water spray.

Kerman has high solar potential. Kerman solar radiation has the right conditions for solar systems, as shown in Fig.1. the annual solar radiation in Kerman is 7625 MJ/m [39]^2. Sunshine duration in Kerman is shown in Fig.2. Schematic of photovoltaic laboratory system is shown in Fig. 3

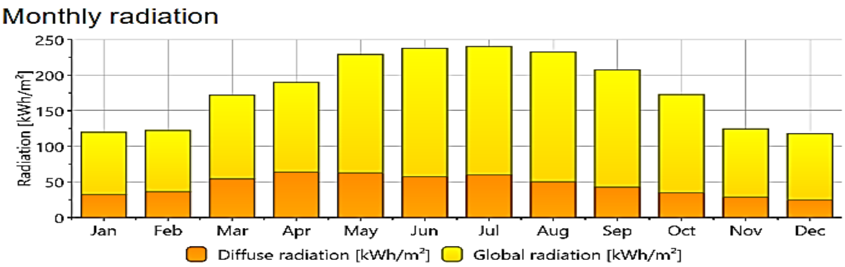


Fig. 1. Kerman solar radiation

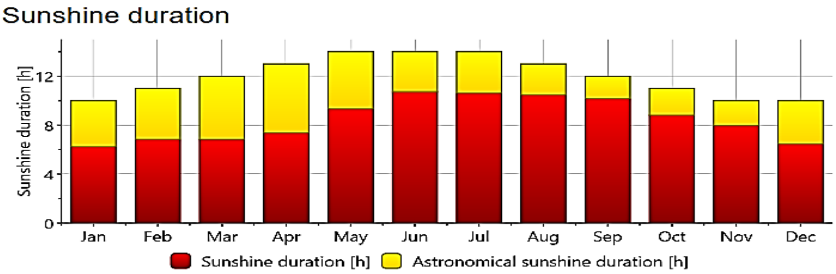


Fig. 2. Sunshine duration in Kerman

According to Fig. 4 and 5, the system consists of six 215 W polycrystalline panels with the specifications of Table (1), the water pump (to supply the water required for spraying water on the panels) and the temperature and path measurement system. Water pump setup (including temperature sensor, relay module, LCD & Keg pad module, contactor, and controller board). It should be noted that the wind speed is measured at a distance of 20 cm from the panel surface.

In this experiment, a controller system was used to record the temperature and control the pump shutdown and shutdown based on the panel temperature. All information was recorded in the 5 minutes' period on November 11, 2016.

It is worth noting that the water used to cool the plates is returned to the water source, which is one of the benefits of this system [3].

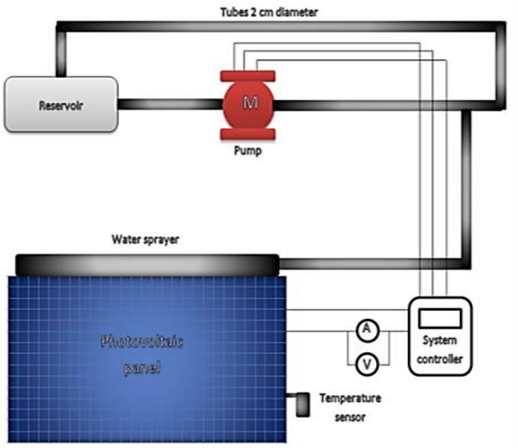


Fig. 3. Photovoltaic Laboratory System

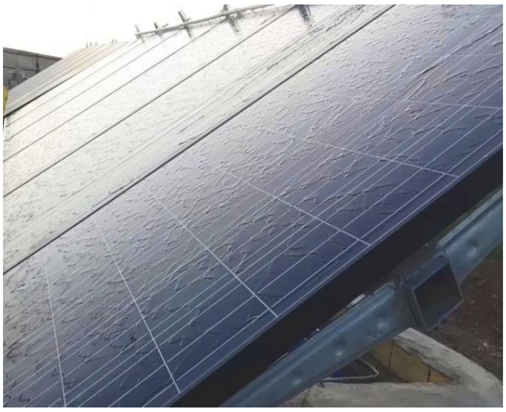


Fig. 4. Photovoltaic system under study

Tabla 1. Photovoltaic Panel Specifications

Manufacturing Data	120721
Standard size	1632*986*42 mm
Max power (p_{max})	215 W
Power tolerance	±0.3%
Max power voltage	28.5 V
Max power current	7.55 A
Open circuit voltage (VOC)	35.7 V
Short circuit current (ISC)	7.92 A
Max system voltage	1 V
Max services Fuse	15 A
Max load	5400 Pa

The test data were taken at 5-min intervals. It should be noted that vector information has been performed with high precision measuring devices.

Fig. 5. Controller system

The recorded information is as follows:

- Power of photovoltaic panel with water spray and without spray
- The amount of radiation reaching the surface of the photovoltaic panel
- Ampere and voltage of photovoltaic panel with water spray and without water spray
- Ambient temperature
- Photovoltaic panel temperature with and without 6. Wind speed

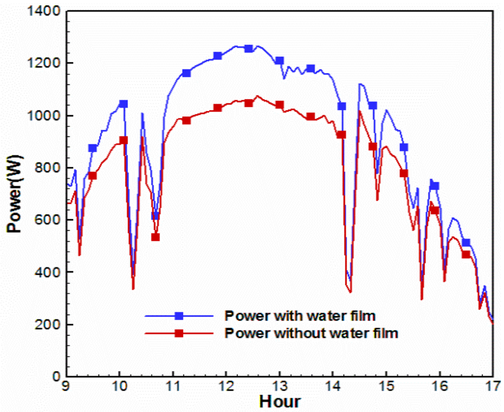
Photovoltaic panel efficiency calculated based on the following equation:

$$\eta_{PV} = \frac{P_{PV}}{GA} \qquad (1)$$

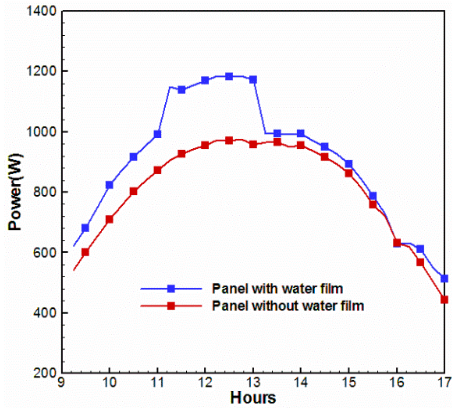
3. Effect of water spraying on photovoltaic panel power

Spraying water on the panel using a water film that moves through the panel allows the panel to reduce the temperature during hot days effectively. So the panel works better throughout the day. The heat transfer process is carried out by the heat transfer between the panel and the evaporative heat.

Figure 6 shows the effects of splashing water on the power of six 215 W crystal panels. The power gain at the output of the panels is about 14.5 %.



(a)



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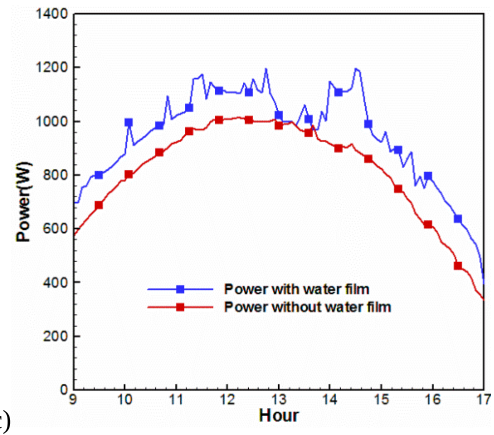
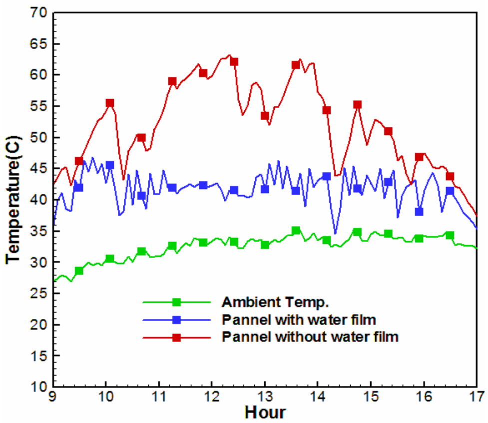


(c)

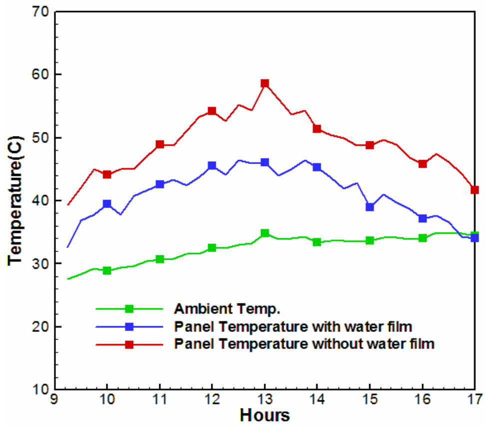
Fig. 6. Comparison of the output power of the panel with and without water spray for 6 polycrystalline panels (215 W)

According to Fig.7, spraying reduces the panel temperature effectively. On average, this temperature drop has to reach 20.19 °C. Therefore, it increases the power output power.

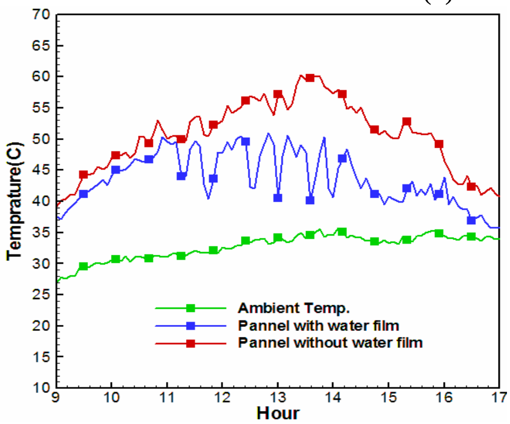
The radiation changes during the experiment day are shown in Fig. 8. Base on Fig. 8, solar radiation and wind speed on 7 July, 11 August, 1 September and 11 October in 2016, on particular days were performed tests.



(a) 7 July 2016

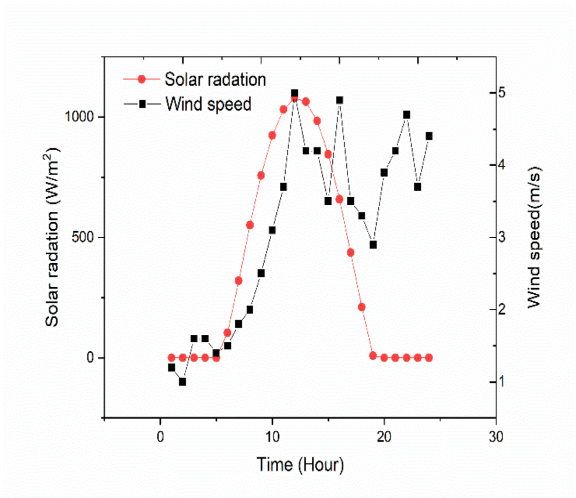


(b) 11 August 2016

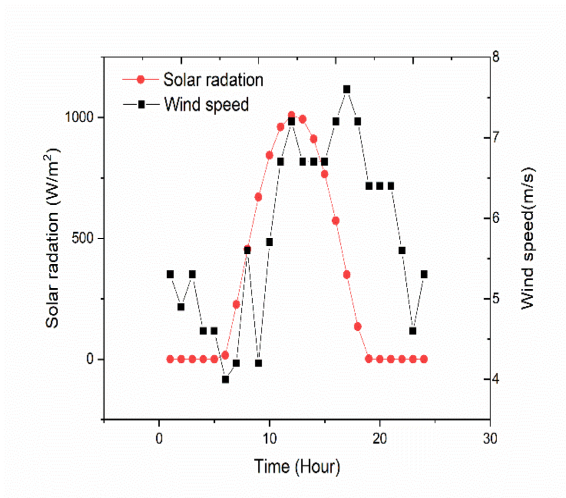


(c) 11 October 2016

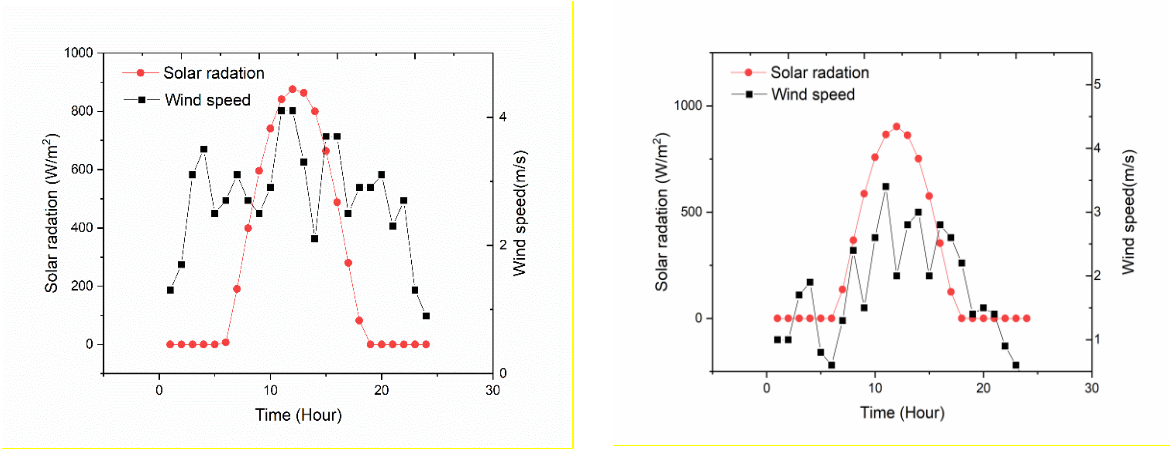
Fig.7. Comparison of panel temperature with and without water spray and ambient temperature variations for six polycrystalline panels (215 W)



(a) 7 July 2016



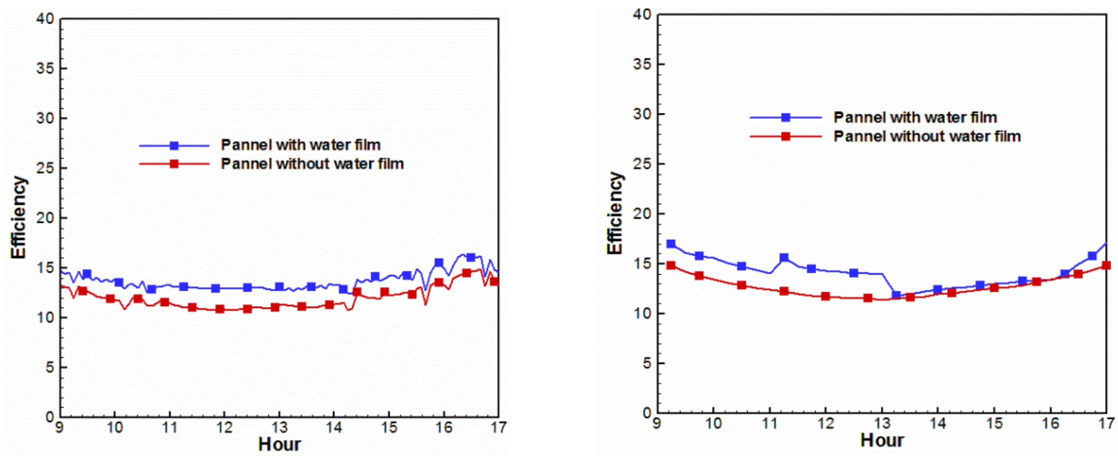
b) 11 August 2016



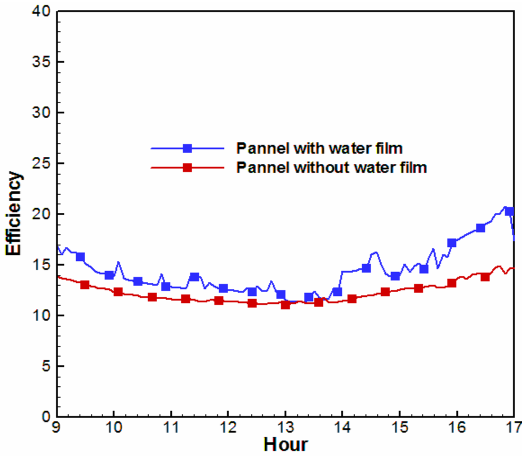
c) 1 September 2016 d) 11 October 2016

Fig.8. Solar radiation and wind speed during the experimented days

Figure 9 shows the effects of water spraying on efficiency. According to this chart, panel efficiency increased by 20%. The presence of clouds has caused drastic changes, and solar radiation has decreased rapidly, and efficiency has increased.



a) 7 July 2016 b) 11 August 2016



c) 11 October 2016

Fig.9. Comparison of panel efficiency with water spraying and non-spraying for six polycrystalline panels (215 W)

It also shows that water spraying brings efficiency closer to the nominal efficiency of the panel most of the day. As mentioned, the water used to cool the panel is returned to the source in this system.

Figure 10 indicates the effects of splashing water on the panel voltage during the test day (20 December). Due to this form of spraying, the average panel voltage has increased by 5.5%.

Therefore, as the cold season approaches and the desired temperature approaches the panel temperature, the output power increases. As a result, the efficiency of the system has increased.

Figure 11 shows the effects of water spraying on the panel flow during the test day. This Figure shows that the radiation performance of the panel also improved during the day of the experiment because the panel flow was directly above its temperature. Therefore, water splashing has the effect of lowering the reflected radiation energy to the surface of the panel. Since photovoltaic panels cannot generate rated power with increasing temperature, it can improve the efficiency of those systems by implementing this scheme for other applications of photovoltaic systems.

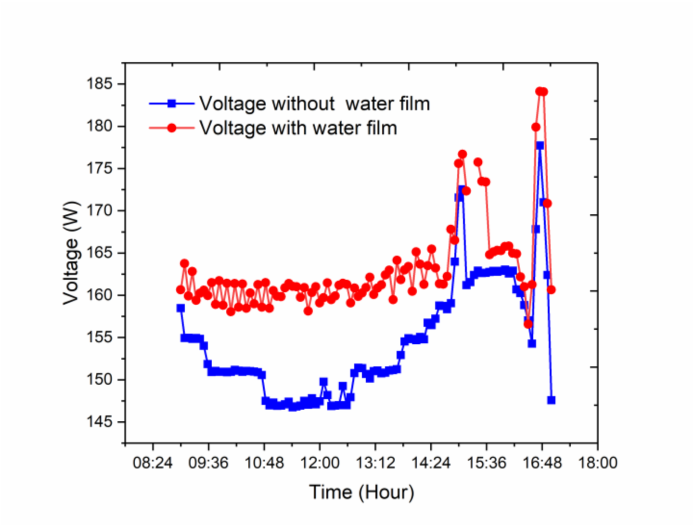


Fig. 10. Comparison of panel voltage with and without water spray for 6 polycrystalline panels (215 w)

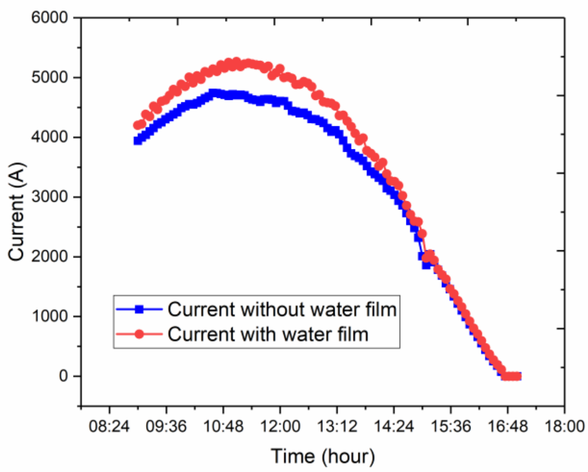


Fig. 11. Comparison of panel flow with water spray and without water spray for 6 polycrystalline panels (215 watts)

It is important to note that from 14:30, cloud formation causes drastic changes in the system. As a result, efficiency and power also change drastically**.**

In thermal photovoltaic systems, airflow is used to cool the system, but the water heat capacity is higher than air; as a result, it performs better, but unfortunately, water scarcity is a major problem that can be attributed to wastewater and wastewater (water used for green space and irrigation). Finally, the use of hybrid technologies is very effective.

4. Conclusion

In this research, the effects of panel cooling by spraying water on photovoltaic panel power were investigated. The results showed that spraying water on the panel effectively reduced the panel temperature. In the hottest hours of the day, this temperature drops to 20.19 °C. Due to the decrease in temperature, the panel's power increased by 14.5%. The efficiency of the test system also increased by 20%, which is a significant Figure. Water spraying can be a good way to improve the performance of photovoltaic systems. One of the problems with this study is high water vaporization; the project uses water waste. Based on the experiments performed in the climatic climate of Kerman province, the appropriate temperature for photovoltaic plates is to achieve the best efficiency of 43-39 °C.

On the other hand, the presence of a thin layer of water on the surface helps to reduce the reflection drop in solar cells. Wind speed plays an important role in the cooling process. The speed of 3km/h is the minimum ideal speed for the test conditions by analyzing the data.

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