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Techno-economic PV evaluation depending on surface water cooling

Abstract: Solar energy is one of the most important renewable energy sources and it can be exploited to produce electrical energy through photovoltaic (PV) panels. PV panels are affected by several factors, the most important being the panel temperature, which greatly affects the performance and efficiency of the PV. This paper investigates the effect of water-based surface cooling on the PV performance. Techno-economic PV evaluation depending on surface water cooling was examined. The effect of changing the water flow rate on the panel temperature was studied. The proposed system studied the effect of using variable water flow rates (1.25, 5, 7 L/min) on the panel temperature. A 260 W poly-crystalline PV panel combined with a water cooling system was examined experimentally. The PV panel temperature, open circuit voltage, short circuit current and output power were measured before and after cooling at variable flow rates. A PV panel analyzer I-V400 was used to test the panel in order to draw the IV and power curves. It was found that the rate of decrease in panel temperature with time is almost constant for all cases. Increasing the rate of water flow on

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the panel surface did not affect the rate of its temperature decrease with time. With the proposed surface cooling technique, the panel temperature decreased from 62.4 to 37.6°C. PV output power increased from 182.65 to 214.62W, with an improvement of around 18%. The amount of energy gained as a result of cooling saves around 0.7USD for one panel per year.

Keywords: solar energy, photovoltaics, PV surface cooling, water cooling, PV performance

Introduction

Renewable sources of energy are being actively utilized as non-traditional energy solutions to mitigate global warming and fossil fuel usage (Velmurugan et al. 2022). Among renewable sources, the most valuable is solar power. Photovoltaics (PV) is one of the most significant technologies since it directly transforms sunlight into electricity (Sharaf et al. 2022). The main disadvantage of PV solar cell is that the increase in temperature reduces its efficiency (Tiwari et al. 2022). Many variables influence the operation of solar panels, involving internal and external factors (Sharaf et al. 2022). Internal factors like panel temperature can be regulated. External factors such as irradiation, ambient temperature, wind speed and dust cannot be regulated.

Temperature is among the factors of greatest significance influencing PV performance (Shaaban et al. 2023). The cell is a semi-conducting current source that operates on the effect of photovoltaics, which means that it receives photons from the sun, causing a voltage difference leading to a photocurrent flow (Velmurugan et al. 2022). While photocurrent is determined by incident radiation, the thermal radiation has negative impacts on the solar cell exposed to this radiation as it increases cell temperature. This temperature affects the panel voltage limiting conversion efficiency. Therefore, there are many PV cooling technologies that can be divided into active cooling and passive cooling (Rajvikram et al. 2019). Active technologies are those in which an external power source is used to reduce the panel temperature. Active cooling includes cooling with air (Amanlou et al. 2018), with water (Sainthiya et al. 2018) or with both (hybrid) (Sasidharan et al. 2018). Passive cooling does not use an external source to cool the panel, cooling occurs naturally, relying on the feature of conduction and convection. This cooling method includes phase change material (Kumar et al. 2020), heat pipe (Han et al. 2020), microchannel heat sink (Ahmed et al. 2021), wick structure (Chandrasekar et al. 2013), and a hybrid approach (Bayrak et al. 2020). Shaaban et al. (2023) reviewed a detailed full study on the effect of different cooling techniques on PV performance.

Water is one of the most effective heat absorbers with a specific heat capacity of 4.2 J/g.K, thus it is used as a heat sink in desert and high temperature areas (Velmurugan et al. 2022). Bhakre et al. (2021) studied the impact of water cooling from different directions; the surface, the back and both on the performance PV panel. One of the advantages of surface cooling is that it solves two problems. It clearly reduces the panel temperature, in addition to the panel cleaning from dust. Hachicha et al. (2015) investigated several water cooling methods to improve PV performance. The results of the experiment showed that cooling from the surface is more effective than cooling from the back, and significantly reduces panel temperature.

Chanphavong et al. (2022) experimentally studied surface water cooling to improve the PV conversion efficiency. The results of the experiment showed that when using a water flow rate sliding on the panel surface of 6 L/min, the panel temperature decreased to 29.6°C compared to the panel without cooling. Elnozahy et al. (2015) studied the effect of automatic PV surface cooling and cleaning on the performance of a system installed on the building rooftop. The results showed that the panel temperature decreased by 45.5% on the surface and 39% on the back. In addition, the panel power output improved from 68.4 W to 89.4 W.

Patel et al. (2023) investigated a PV cooling method by sliding water over the panel surface at a constant flow rate. The panel temperature decreased by 3.54°C on the surface while 2.79°C on the back. An improvement in efficiency of 9.64% on average was achieved through surface cooling. Khalil et al. (2019) also studied the effect of water cooling on the performance of PV panels. However, in this case the three cooling methods (surface, back and hybrid) were applied. The results showed that energy was improved by 15.5% with surface cooling, 13.97% with back cooling, and 17.4% with hybrid cooling compared to the panel without cooling. Azimi et al. (2024) presented an algorithm to optimize a water cooling system to maximize the energy produced by a PV panel. It was noticed from the system that the efficiency improved from 13.85 to 14.86%.

Ahmed et al. (2023) studied the effects of solar radiation, panel temperature, water cooling and dust accumulation on the performance of a 50 W PV panel. It was found that the output power from the panel was improved by 20.47% when using 0.0045 m^3/min water circulation rate in the cooling cycle. Panda et al. (2023) performed experiments to study the effect of surface and back water cooling on the PV array performance. The water was made to flow on the surface at a certain flow rate to cool the surface, while wet grass cooled the back of the PV. The results showed an output power improvement of 28.6%.

From research papers mentioned in the literature review, it was found that the effect of water cooling on the performance of photovoltaic panels was studied using a closed loop water cycle at a fixed flow rate. It was also found that an open cooling circuit was not used and therefore the effect of changing the flow rate on the rate of temperature drop was not studied. In the current paper, the effect of an open loop cycle using water surface cooling on the PV performance was studied experimentally. The effect of changing the fresh water flow rate on the panel temperature was examined. The proposed system studied the effect of using variable water flow rates (1.25, 5, 7 L/min) on panel temperature. In addition, the effect of using the lowest flow rate on the PV performance was studied.

1. Factors influencing the performance of PV cells

Many variables influence the performance of PV panels involving solar irradiation and panel temperature (Sharaf et al. 2022). In addition, panel efficiency is also influenced by a number of external factors, including wind speed, dust, humidity and shade (Ahmed et al. 2023).

a) Solar irradiance

The output power generated by a PV is directly proportional to the amount of collected irradiation (Maleki et al. 2020). The intensity of irradiance changes throughout the day, reaching its peak at midday. When a surface of a panel is faced perpendicular to the sunlight, it receives the most solar irradiation. To get the best energy generation rates, the PV inclination angle must be chosen based on its geographical location. PV panels can be mounted on a solar tracker to trace the appropriate path perpendicular to the sun and collect the greatest amount of irradiation.

The quantity of photons collected by semiconductors influences the short circuit current (I_{SC}), which is consequently connected to light intensity (Dwivedi et al. 2020). The efficiency of the conversion is thus relatively constant in such a manner that the output power is normally related to irradiance, although it decreases as the panel temperature increases. The open-circuit voltage (V_{OC}) fluctuates only slightly with the intensity of the light.

b) Dust accumulation

Sunlight can be partially blocked by dust or dirt, reducing the quantity of absorbed solar energy and, as a result, affecting the output rate of the solar panel (Maleki et al. 2020). A dust layer on the panel surface reduces the rate of the output to around 7%. Dust is defined as pulverized microscopic particles with a diameter less than 500 μm (Dwivedi et al. 2020). Dirt is the second environmental factor, which is determined by how it is distributed on the PV panel, as well as its density and size. The exact amount and size of the dust particle deposition on the PV surface determines the efficiency loss. In the arid environment, particle deposition on the surface of the panel is particularly intense. Thus, solar output is reduced by roughly 40%.

c) Shade

The effect of shade reduces the output of the PV significantly (Maleki et al. 2020). Because the cells are connected in series, shade affects the current inside the cells as well as the entire panel. Shade on the PV panel is due to the shadow projection of any object located in the panel area or due to dust deposition, which, if uniform over the panel, may indicate a thermal runaway on the module (Dwivedi et al. 2020). Similarly, when partial, hot spots on the solar panel might form. The loss of electrical power from partial shade and hot areas might exceed 70%.

d) Humidity

The quantity of water in the air is known as air humidity (Dwivedi et al. 2020). Relative humidity is frequently used for determining the air humidity, or the moisture quantity in the air. In accordance with various studies, two factors are frequently taken into account when evaluating the influence of moisture . The first is the influence of water vapor particles on irradiation, and the second is the humidity effect during entrance into the PV panels. As the temperature fluctuates during the day, so does the relative humidity. Temperature and humidity have an opposite relationship. The presence of humidity accelerates the deterioration of a PV panel. Furthermore, humidity stops the panel from fully absorbing sunlight (Maleki et al. 2020). When the relative humidity is high, a water vapor layer accumulates on the panel surface towards the sun rays, which leads a partial loss of absorbed energy. Moreover, the relative humidity influences capillary adhesion between the dust particles and the surface, accelerating the process of the deterioration resulting from debris and dust.

e) The effect of wind

It might not be true to assert that wind velocity has a direct impact on the efficiency of solar panels (Dwivedi et al. 2020). It does, however, play a significant part in solar energy production. When the wind blows, the panel temperature falls. The wind cools the PV modules, causing reduced oscillation of the electrons, allowing them to transport more energy as they go to the upper state. The PV panel is 0.05% more efficient when it is cooled by 1 degree Celsius.

f) Temperature

The PV operating temperature is one of the most critical elements influencing the panel output (Maleki et al. 2020). Ambient temperature, wind speed, irradiation and other factors all influence this temperature. Raised panel temperatures are caused by higher irradiation and ambient temperature. Semiconductors are the fundamental components of solar PVs, and owing to their inherent properties, a rise in temperature will immediately cause efficiency loss. The linear decrease in Voc as panel temperature increases is the primary source of efficiency loss. The efficiency of crystalline cells drops by around 0.5% for every 1°C increase in the panel temperature. Figure 1 presents the effect of the increase in temperature on open circuit voltage and the short circuit current (Panda et al. 2023).

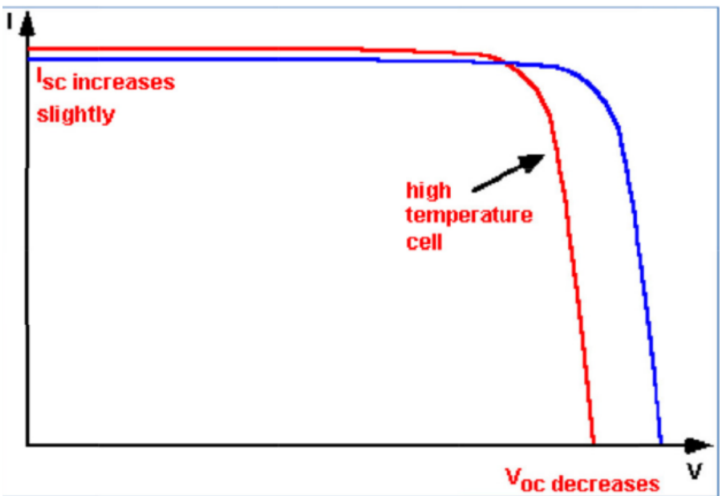

Fig. 1. Effect of temperature on PV characteristics (Panda et al. 2023)

Rys. 1. Wpływ temperatury na charakterystykę PV

Many different cooling methods (active and passive) have been investigated to improve PV performance. Active cooling methods are those that require external equipment, whether electrical or mechanical, to extract the heat absorbed from PV panels, such as fans, blowers and pumps (Shaaban et al. 2023). Passive cooling methods are those do not require any external equipment as the heat is extracted naturally. Figure 2 shows a block diagram which classifies the different cooling technologies for photovoltaic panels.

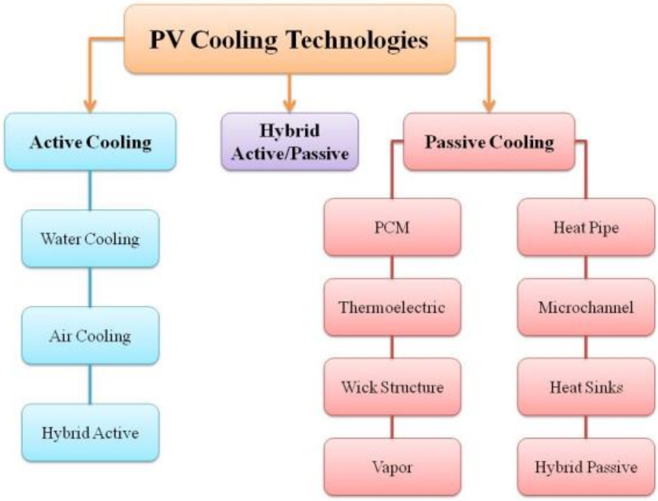

Fig. 2. Block diagram of PV cooling technologies (Shaaban et al. 2023)

Rys. 2. Schemat blokowy technologii chłodzenia PV

As shown in Figure 1, when the panel temperature increases, the open circuit voltage significantly decreases and the short circuit current slightly increases. As a result, the PV output power decreases.

2. System and methodology

A 260 W poly-crystalline PV panel combined with a water cooling system was examined experimentally. The experimental setup was installed on the rooftop of the National Research Centre at Giza, Egypt. Figure 3 shows the IV and power curves for the used PV panel. The Voc, Isc and maximum power levels of the panel are 38.1V, 8.91A and 260 W, respectively. The PV panel temperature, open circuit voltage, short circuit current and output power were measured before and after cooling at variable flow rates. An I-V400 PV panel analyzer was used to test the panel in order to draw the IV and power curves.

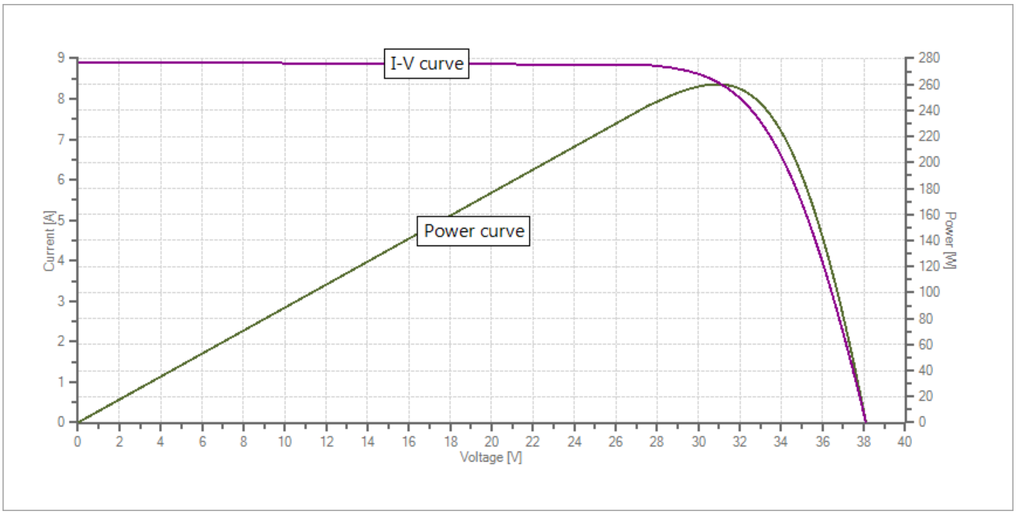

Fig. 3. IV and power curves of the PV panel

Rys. 3. Krzywe IV i mocy panelu PV

During the summer season in Egypt, the average ambient temperature is around 35°C, accompanied by approximately nine hours of sunlight, whereas in winter, the temperature averages around 19°C with about six hours of sunlight. Consequently, the necessity to cool PV panels in Egypt is more pronounced during summer rather than winter for around seven hours daily. Therefore, the research was conducted during the high temperature months due to the relatively stable climatic conditions. Factors like humidity and wind were not included in the scope of this study because the main objective was to study the effect of changing the flow rate on the temperature decreasing.

The proposed system was to study the effect of the surface cooling on the performance of the panel in addition to investigating the effect of using variable water flow rates on the panel temperature. The PV cooling system comprised a fresh water PVC pipe placed at the maximum point above the panel surface, as shown in Figure 4. The pipe had a diameter of 1.27 cm and a length of 1.5 m, enough to span the entire panel length. Nozzles, with a diameter of 1 mm, were distributed in a way that allows water to slide in order to completely cover the panel to be cooled. The cooling system was of the open loop type and didn't need any external power (passive cooling), meaning that water was used once directly from the source. The used water was drained so it could be used in other applications, such as heating, etc.

The fresh water supply pipe was connected to a valve that controlled the water flow rate entering the cooling pipe. The cooling system also contained a flow meter to measure the water flow rate. A photovoltaic analyzer device was connected to the output of the solar panel in addition to the K-type temperature sensor behind the panel to measure its temperature. A valve that controlled the opening and closing of water at different flow rates over a wide range from 0-100% based on the measurement of the water meter connected to the system.

Fig. 4. Experimental PV panel setup

Rys. 4. Eksperymentalna konfiguracja panelu fotowoltaicznego

The PV panel analyzer IV-400 w was connected to the cooled panel to measure the irradiation, panel temperature, open circuit voltage, short circuit current and the output power. Also, the device is used to draw IV and power curves for the PV panel. The cooling system was operated at several water flow rates to reach the lowest possible rate that would allow the panel to be covered with water. It was found that the minimum flow rate that ensured the panel was covered with water was at 1.25 L/min. The experiment was conducted at flow rates 1.25, 5 and 7 L/min. The open circuit voltage, short circuit current and power of the cooled panel were measured at each flow rate before and after the cooling.

3. Result and discussion

The main goal of the proposed system is to study the rate of change in the panel temperature as a result of cooling over time and at different water flow rates to determine the effect of changing the flow rate on the rate of temperature decrease. The cooling effect on the performance of the solar panel and increase in the energy output were calculated which, of course, reduces the cost of producing electricity and reduces the payback period of solar panels.

It was found that the minimum flow rate that ensures the panel is covered with water is 1.25 L/min. The system is designed to study the effect of surface cooling on panel performance and to study the effect of using variable water flow rates (1.25, 5, 7 L/min) on the panel temperature. Each experiment commenced when the panel temperature reached approximately 50°C. Table 1 shows the PV panel parameters before and after cooling for all three cases. These three cases were tested and the results are discussed in the following subsections.

Table 1. PV panel parameters before and after cooling for all cases

Tabela 1. Parametry paneli fotowoltaicznych przed i po schłodzeniu dla wszystkich przypadków

PV Panel parameters	Case 1 (1.25 L/min)		Case 2 (5 L/min)		Case 3 (7 L/min)	
	before cooling	after cooling	before cooling	after cooling	before cooling	after cooling
T_{PV} [°C]	51.5	40	49.6	38.5	50.5	39.3
P_{max} [W]	138.5	148.3	128.2	136	140.3	149.2
V_{oc} [V]	33.7	35.2	34.1	35	34	36.3
I_{sc} [A]	5.82	5.85	5.28	5.36	5.85	5.64
I_r [W/m^2]	595	593	593	587	600	590
V_{oc} at P_{max} [V]	26.7	28.3	28.3	27.4	27.1	29.6
I_{sc} at P_{max} [A]	5.18	5.24	4.69	4.82	5.18	5.04

3.1. Flow rate 1.25 L/min (Case 1)

In this case, the water flow rate on the surface of the panel was 1.25 L/min, which as previously mentioned is the minimum flow rate that ensures that the panel surface is covered with water. The experiment commenced at a panel temperature of 51.5°C. The temperature decreased as a result of cooling to 40°C in a time of 4 mins (Fig. 5).

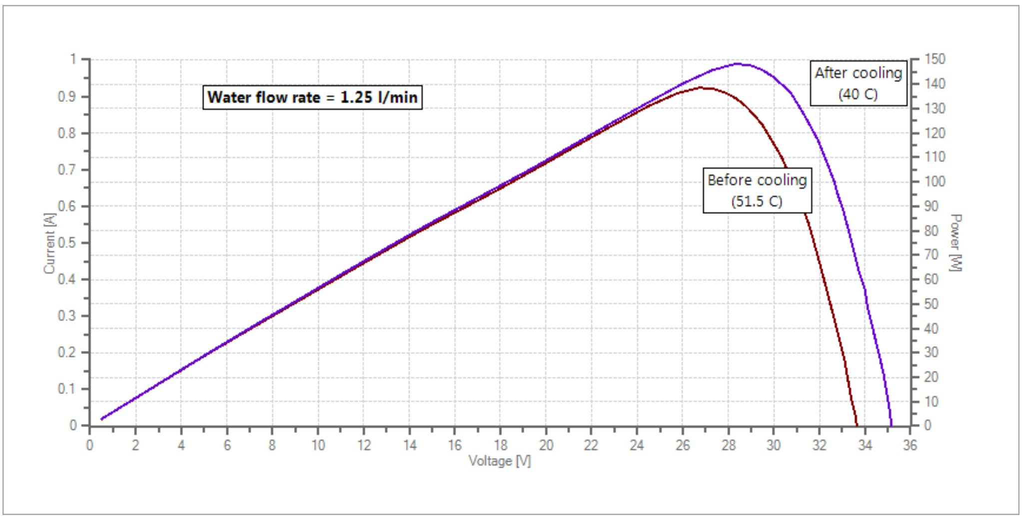

Fig. 5. PV power curve before and after cooling at 1.25 L/min water flow rate (CASE 1)

Rys. 5. Krzywa mocy fotowoltaicznej przed i po schłodzeniu przy natężeniu przepływu wody 1,25 l/min (przypadek 1)

As shown in Figure 5, the maximum power of the panel increased from 138.5 to 148.3 W as a result of cooling, with a 7% improvement at 594 W/m^2 of irradiation on average. The open circuit voltage increased as a result of cooling from 33.7 to 35.2 V. It can also be seen in Figure 5 that the panel temperature took 4 mins to decrease by 11.5°C which equates to a decrease rate of 2.9°C per minute.

3.2. Flow rate 5 L/min (Case 2)

In this case, the water flow rate on the surface of the panel was 5 L/min. The experiment commenced at a panel temperature of 49.6°C. The temperature decreased as a result of cooling to 38.5°C in a time of 4 mins (Fig. 6).

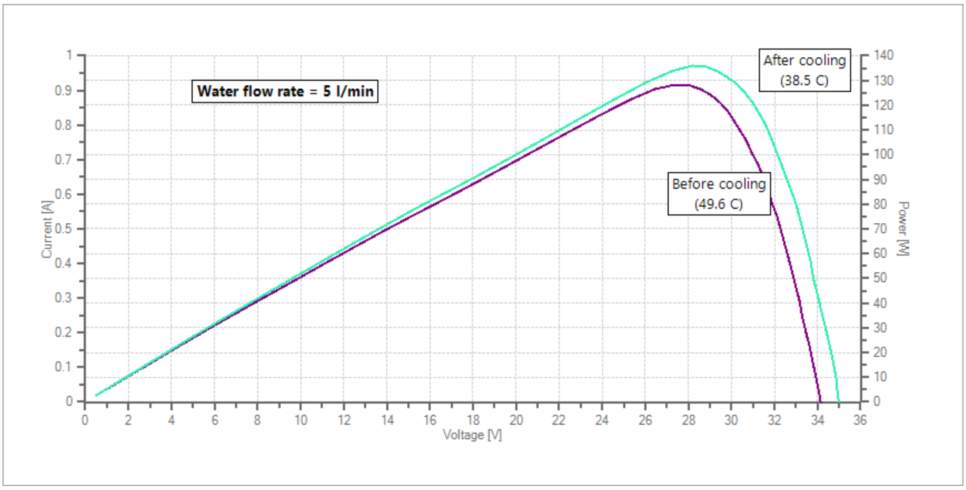

Fig. 6. PV power curve before and after cooling at 5L/min water flow rate (CASE 2)

Rys. 6. Krzywa mocy fotowoltaicznej przed i po schłodzeniu przy przepływie wody 5 l/min (przypadek 2)

As shown in Figure 6, the maximum power of the panel increased from 128.2 to 136 W as a result of cooling, with an average improvement of 6% at 590 W/m^2 of irradiation. The open circuit voltage increased as a result of cooling from 34.1 V to 35 V. Figure 6 shows that the panel temperature took 4 minutes to decrease by 11.1°C – a decrease rate of 2.8°C per minute.

3.3. Flow rate 7 L/min (Case 3)

In this case, the water flow rate on the surface of the panel was 7 L/min. The experiment was started at a panel temperature of 50.5°C. The temperature decreased as a result of cooling to 39.3°C in a time of 4 mins, as shown in Figure 7.

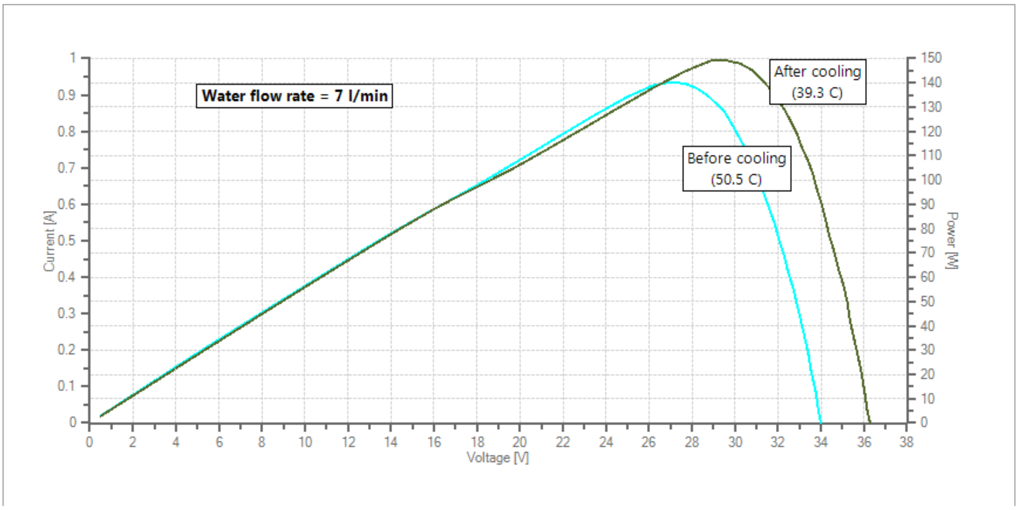

Fig. 7. PV power curve before and after cooling at 7 L/min water flow rate (CASE 3)

Rys. 7. Krzywa mocy fotowoltaicznej przed i po schłodzeniu przy przepływie wody 7 l/min (przypadek 3)

As shown in Figure 7, the maximum power of the panel increased from 140.3 to 149.2 W as a result of cooling with an average improvement of 6% at 595 W/m^2 of irradiation. The open circuit voltage increased as a result of cooling from 34 to 36.3 V. It was also found that the panel temperature took 4 mins to decrease by 11.2°C – a decrease rate of 2.8°C per minute.

The aim of the previous three cases was to study the effect of using different flow rates on the rate of change of the panel temperature over time, Figure 8 illustrates this relationship.

As illustrated in Figure 8, it was found that the rate of decrease in panel temperature with time is almost constant for all cases – increasing the rate of water flow on the panel surface did not affect the rate of its temperature decrease with time. Therefore, using the lowest water flow rate is sufficient to achieve the desired cooling result. This is providing that the flow rate is sufficient to ensure that the panel is completely covered with water, as previously indicated in Case No. 1. The reason why the rate of temperature drop does not change with the changing flow rate is due to the use open loop cooling cycle. Fresh water was used directly from the source at an almost constant temperature. This saves the energy consumed if an electric circulation pump is used as in closed loop cooling cycles, in addition to the fact that the water used for cooling is considered clean, non-wasted water and can be reused as warm water in many applications.

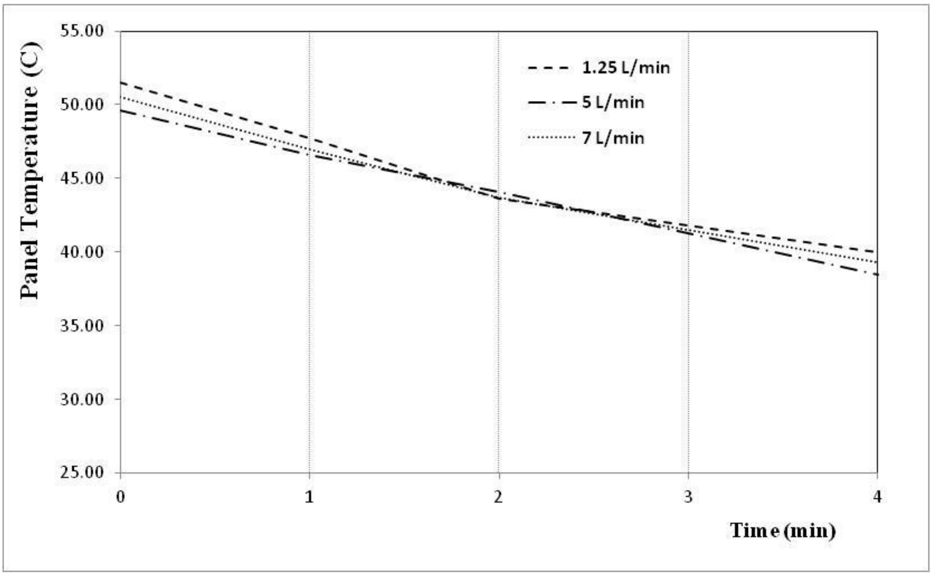

Fig. 8. PV panel temperature versus time at different water flow rates

Rys. 8. Temperatura panelu fotowoltaicznego w funkcji czasu przy różnych natężeniach przepływu wody

3.4. PV performance enhancement

The experiment was performed on another day at the lowest water flow rate, which was 1.25 L/min, to study the effect of surface cooling on the performance of the solar panel. The experiment was conducted at a solar radiation of 850 w/m^2 – the results are presented in Figure 9.

It can be seen in Figure 9 that the temperature of the panel before the start of cooling was 62.4°C, and after cooling it decreased to 37.6°C in a time of 8 mins. The power of the panel improved to 214.6W compared to 182.6W before cooling, with an improvement equivalent to approximately 18%.

Although solar radiation is much higher compared to previous cases, and consequently the panel temperature, it can be noticed from this experiment that the results are also identical to the previous three cases. The panel temperature was reduced by 24.8°C in 8 mins, compared to a reduction of approximately 12°C in 4 mins in the previous cases.

Studying the rate of change of the panel temperature during and after cooling, it was found that initially the panel temperature decreased at a rate of over 6°C every minute. After that, the temperature dropped by 2°C every minute before the panel reached the lowest possible temperature. After stopping cooling, the panel temperature rose at a rate of 1.5°C every minute. Figure 10 shows the water control valve condition over time.

From Figure 10, it can be seen that the water flow valve is set to open for one minute and close for one minute – the valve is open for 30 mins each hour and for around 3.5 hours per day.

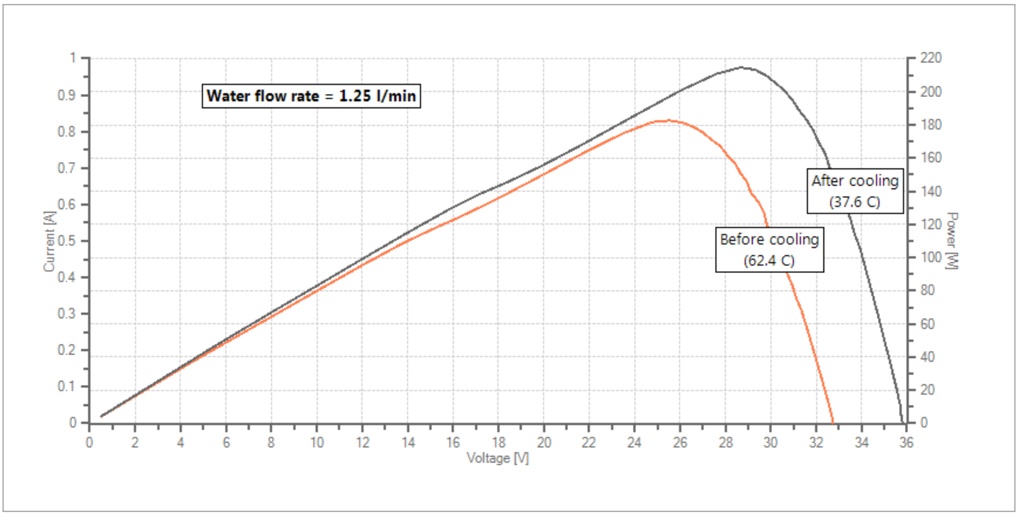

Fig. 9. PV power curve before and after 8 minutes of cooling at 1.25 L/min water flow rate

Rys. 9. Krzywa mocy fotowoltaicznej przed i po 8 minutach chłodzenia przy natężeniu przepływu wody 1,25 l/min

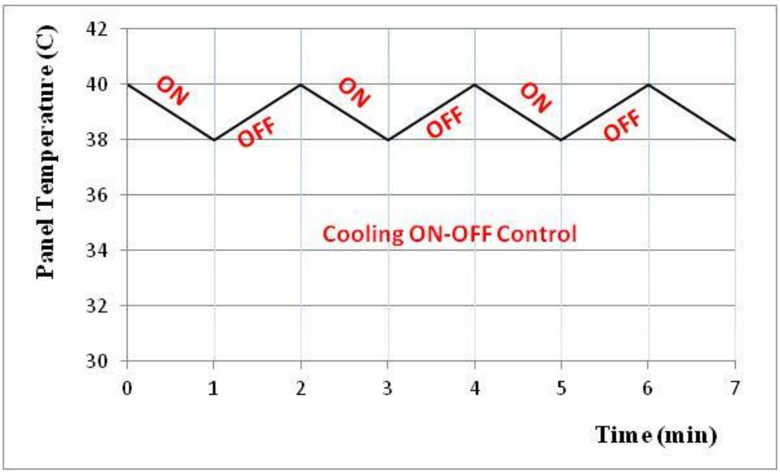

Fig. 10. Water flow control

Rys. 10. Kontrola przepływu wody

thus, the total water consumption per day = water flow rate (L/min) × Time (min in per day) = $1.25 \cdot 30 \cdot 7 = 262.5$ L = 0.2625 m^3

The cooling system works for 5 months per year (high temperature months)

The total water consumption per year = the total water consumption per day (m^3) · No. of days = $0.2625 \cdot 150 = 39.375$ m^3

The cost of consumed water per year = the total water consumption per year (m^3) · tariff (USD/m^3) = 39.375 · 0.01667 = 0.656 USD

The cooling system comprises, as mentioned before, 1.5 m PVC cooling pipe for each panel and one valve for all PV system. The cost of them was 0.625 USD.

Assuming the lifetime of the cooling system is equal to the lifetime of PV system (25 years)

Thus, the annual cost of the cooling system = 0.625 / 25 = 0.025 USD

The total annual consumption of the cooling system = 0.656 + 0.025 = 0.681 USD

Energy gain per year = (Panel output power with cooling – Panel output power without cooling) · No. of working cooling hours per year = (214.6 – 182.6) · 150 days per year · 7 hrs per day = 33.6 kWhr

The annual cost of energy gain = Energy gain per year (kWhr) · tariff (USD/kWhr) = 33.6 · 0.021 = 0.7 USD

Thus, the annual saving = 0.7 – 0.681 = 0.019 USD

This is based on the assumption that the water will be wasted. However, as mentioned previously, the water used for cooling is clean and can be used in many applications. In this case, the amount of energy gained will be saved as a result of cooling, which is equivalent to about 0.7 USD for one panel per year.

Conclusions

PV Cooling solar is necessary to improve the performance of solar panels in addition to cleaning the panel from dust. The proposed system was used to study the effect of surface cooling on panel performance and to study the effect of using variable water flow rates (1.25, 5, 7 L/min) on panel temperature. A 260 W poly-crystalline PV panel combined with a water cooling system was examined experimentally. The PV panel temperature, open circuit voltage, short circuit current and output power were measured before and after cooling at variable flow rates. It was found that the panel temperature took 4 mins to decrease by 11.5, 11.1 and 11.2°C at water flow rates of 1.25, 5 and 7 L/min, respectively. This means that the rate of decrease in panel temperature over time is almost constant for all cases. Thus, increasing the rate of water flow on the panel surface did not affect the rate of its temperature decrease over time. Therefore, using the lowest water flow rate is sufficient to achieve the desired cooling result. This is due to the use of an open loop cycle that keeps the feeding water at a constant temperature. This makes the temperature drop rate constant even when the flow rate changes.

The experiment was performed on another day at the lowest water flow rate, which was 1.25 L/min. The effect of surface cooling on the performance of the solar panel was studied. With the proposed cooling method, it was observed that the temperature of the panel before the start of cooling was 62.4°C, and after cooling it decreased to 37.6°C. The power of the panel improved to 214.6 W compared to 182.6 W before cooling, with an improvement equivalent to approximately 18%. This resulted in a 33.6 kWhr energy gain per year due to cooling.

The Authors have no conflicts of interest to declare.

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Ocena techniczno-ekonomiczna PV w zależności od chłodzenia wodą powierzchniową

Streszczenie

Energia słoneczna jest jednym z najważniejszych odnawialnych źródeł energii i może być wykorzystywana do produkcji energii elektrycznej za pomocą paneli fotowoltaicznych (PV). Na panele PV wpływa kilka czynników, z których najważniejszym jest temperatura panelu, która w znacznym stopniu wpływa na wydajność i sprawność PV. W niniejszym artykule zbadano wpływ chłodzenia powierzchniowego na bazie wody na wydajność PV. Przebadano techniczno-ekonomiczną ocenę PV w zależności od chłodzenia wodą powierzchniową. Przebadano wpływ zmiany szybkości przepływu wody na temperaturę panelu. Proponowany system zbadał wpływ stosowania zmiennych szybkości przepływu wody (1,25, 5, 7 l/min) na temperaturę panelu. Eksperymentalnie zbadano polikrystaliczny panel PV o mocy 260 W połączony z systemem chłodzenia wodą. Temperaturę panelu PV, napięcie obwodu otwartego, prąd zwarcia i moc wyjściową mierzono przed i po schłodzeniu przy zmiennych szybkościach przepływu. Do przetestowania panelu w celu narysowania krzywych IV i mocy użyto analizatora paneli PV I-V400. Stwierdzono, że szybkość spadku temperatury panelu w czasie jest prawie stała we wszystkich przypadkach. Zwiększenie szybkości przepływu wody na powierzchni panelu nie wpłynęło na szybkość spadku jego temperatury w czasie. Dzięki proponowanej technice chłodzenia powierzchni, temperatura panelu spadła z 62,4 do 37,6°C. Moc wyjściowa PV wzrosła z 182,65 do 214,62 W, co stanowi poprawę o około 18%. Ilość energii uzyskanej w wyniku chłodzenia pozwala zaoszczędzić około 0,7 USD na jeden panel rocznie.

Słowa kluczowe: energia słoneczna, fotowoltaika, chłodzenie powierzchni PV, chłodzenie wodne, wydajność PV