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Increasing the Efficiency of the Solar Cell by Using a Heat Exchanger Technique

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One of the problems that arise when generating renewable energy (using solar cells) in the world and in Iraq especially is high outside temperatures. Because of the properties of crystalline silicon used in the manufacture of solar cells, the electrical performance of solar panels is greatly affected by the operating temperature of silicon solar cells, which leads to a decrease in the energy generated by these cells increasing their temperature. In addition, to control this decrease in energy, the solar panels were cooled using a heat exchanger that uses water as a coolant. The heat exchanger technique can potentially increase the efficiency of a solar cell by using the waste heat generated during the photovoltaic process. This heat can be captured and used for pre-heating a water that is then passed through a heat exchanger, which transfers the heat to the outside. This can improve the overall efficiency of the solar cell. In this research, a copper heat exchanger has been used for cooling a solar cell and studying the effect of this cooling method on the temperature and efficiency of the PV. We used a source of light and warmth. With a halogen lamp, the results showed an accelerating manner, as the temperature of the solar cell increased, the open-circuit voltage decreased, but when using the heat exchanger, the temperature of the cell rose slowly, so the open-circuit voltage decreased slower compared to the first case during the same period, and this leads to the PV working with a higher efficiency under the same conditions.

Keywords: solar cells, PV, cooling, heat exchanger, heat transfer.

Introduction

A photovoltaic cell is a device that converts light energy into electrical energy through the photovoltaic effect [1]. Photovoltaic cells are made of materials, such as silicon, that have the ability to absorb photons from sunlight and release electrons, creating a flow of electricity [2]. These cells are connected to a solar panel to generate more power, and multiple panels can be connected to form a solar array for large-scale electricity generation. High temperatures can hurt the performance of a solar cell [3]. When temperatures increase, the efficiency of a solar cell decreases because the higher heat causes the electrical resistance of the materials in the cell to increase, leading to a reduction in the flow of electric current. Additionally, high temperatures can also cause permanent damage to the cell, such as warping or cracking [4-6]. To counteract the effects of high temperatures, solar cells are often designed with cooling systems or housed in shading structures to reduce the amount of heat they are exposed to. In this paper, we will use a heat exchanger technique that can increase the efficiency of a solar cell by allowing for the removal of excess heat, which can cause the temperature of the cell to rise and negatively impact its performance. By utilizing a heat exchanger to transfer the excess heat away from the cell, the temperature can be regulated, leading to improved efficiency [7-9]. Additionally, the recovered heat from the heat exchanger can be used for other applications, making the system more energy-efficient and sustainable. It is one of the important values that directly affects the efficiency of the photovoltaic [10-12].

The aim of this research is to overcome the problems that arise when generating renewable energy (using solar cells), which is characterized by high temperatures. experience shows that the electrical performance of solar cells is greatly improved with the decrease of the temperature of solar cells, which leads to avoiding a reduction in the energy

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generated by these cells when their temperature increases.

The theory

Increasing the solar cell temperature (T_C) negatively affects the open-circuit voltage (V_{OC}) in the solar cell as well as the intensity of solar radiation [13-15], as the V_{OC} is a function of the temperature of the solar cell and the intensity of solar radiations [16-18]:

$$V_{OC} = f\left(S, T_C\right), \qquad (1)$$

where T_C - PV temperature °C; S - Solar radiation, W/m^2.

The temperature is taken from the average surface temperature of the upper surface and the temperature of the lower surface to calculate the temperature of the solar cell (T_C) [19-21]:

$$T_C = T_{AV} = \left(T_{bottom} + T_{top}\right)/2. \qquad (2)$$

The heat sensor was placed on the bottom surface of the solar cell, and because of the presence of the heat source at the top, no sensor was installed on the cell surface, and in this way, the work was approved. As for the copper tube heat exchanger, where water circulates at a constant speed (1 m/s) to heat exchange from the solar cell to the outside environment (see fig. 1), employing the contact between the solar cell and the heat exchanger [22] high heat exchange load, leads to the lower the cell temperature, and thus the increase in the electric powers of it [23, 24].

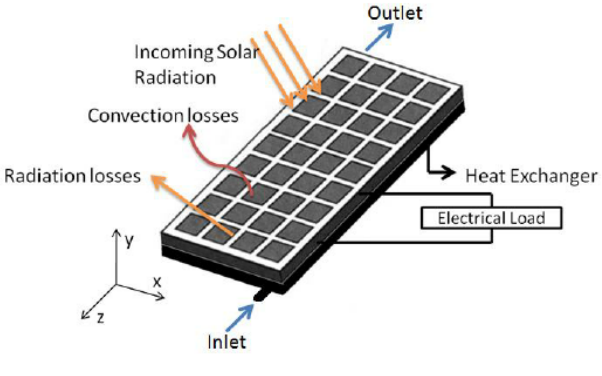

Fig. 1. Schematic diagram of a heat exchanger with a solar cell [25]

The practical study

In this study, a solar panel was used to obtain voltage, and the conformances were shown in the figure 1 shows the method of installing the solar cell (10·5.0) cm^2 & thickness (3.0 cm) on the heat exchanger as well as the location of the heat source, which is a lamp with a capacity of 500 watts, it is 60 cm above the photovoltaic cell, Which represents a thermal and light source for the photovoltaic cell [26], resulting in an increase in the temperature of the cell during the study [27]. The two ends of the photovoltaic cell were also connected to a voltmeter to record the open-circuit voltage, with a thermometer at a distance of 1 meter from the top of the photovoltage cell.

I. Reading and recording the temperature of the bottom surface of the cell and the values of the open-circuit voltage, V_{OC}, every three minutes for 30 minutes. Since the light source is turned on, as shown in Table 1.

II. The heat exchanger, which was specially designed to cooling the solar cell, was installed, as well as the sensor, which was previously described, was installed under the photovoltaic cell to ensure good heat transfer.

Record the values of the open-circuit voltage (V_{OC}), as well as the temperature of the bottom surface of the PV, and the results were recorded Table (2) and Figure (1), it shows the PV installed on the heat exchanger.

Table 1. **Change of temperature and open-circuit voltage per time without the heat exchanger**

PV without heat exchanger		
The time, min	Voltage, *V*	Temperature, °C
3	6.49	7
6	6.25	14
9	6.12	22
12	5.95	27.5
15	5.88	29.5
18	5.82	34
21	5.81	35.5
24	5.79	37.5
27	5.77	38
30	5.76	39

Table 2. **Change of temperature and open circuit voltage per time with a heat exchanger**

PV with heat exchanger		
The time, min	Voltage, *V*	Temperature, °C
3	6.61	7
6	6.52	11
9	6.48	13
12	6.43	16.5
15	6.38	17.5
18	6.34	18.2
21	6.33	18.4
24	6.29	18.5
27	6.28	22
30	6.27	22.1

Results and discussions

We note that with the absence of the heat exchanger, a rise in the temperature of the photovoltaic leads to a decrease in the open-circuit voltage, and this voltage drop occurs due to the rapid increase in the temperature of the PV. In the case of installing the heat exchanger, we note (figure 3) that the decrease in the open-circuit voltage is slowly due to the slow rise in the temperature of the photovoltaic cell. The rise in temperature of the solar cell at the same time is less than the use of the heat exchanger and without using it, see Figure 2. The improvement in the performance of the photovoltaic cell appears in the figure 3, which shows the rate of increase in voltage and maintaining its value in the same period when using the heat exchanger, and this performance appears when comparing the difference in temperatures ΔT and voltages ΔV_{oc} in the two cases.

With heat exchanger: ΔT = 1.8°C, ΔV_{OC} = = 0.034 V.

Without heat exchanger: ΔT = 3.2°C, ΔV_{OC} = = 0.073 V.

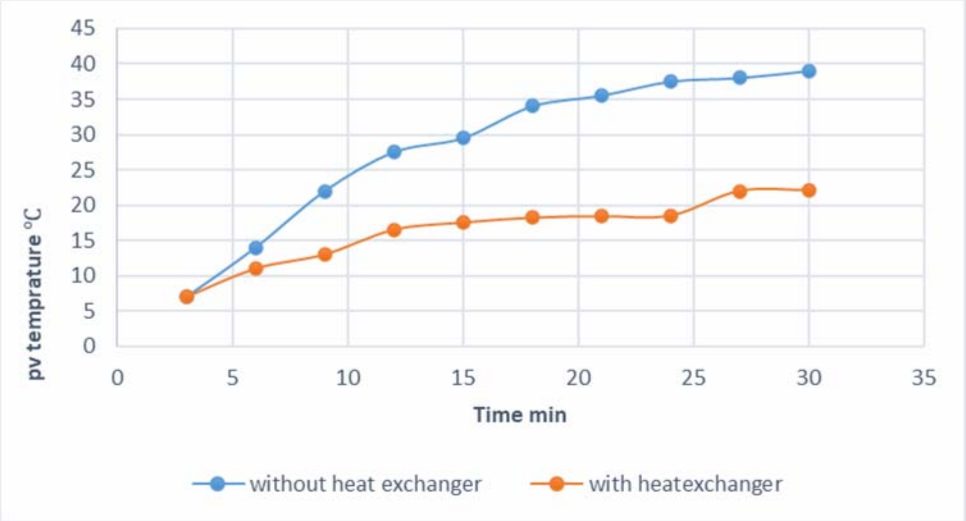

Fig. 2. The temperature change in the solar cell per time (with and without heat exchanger)

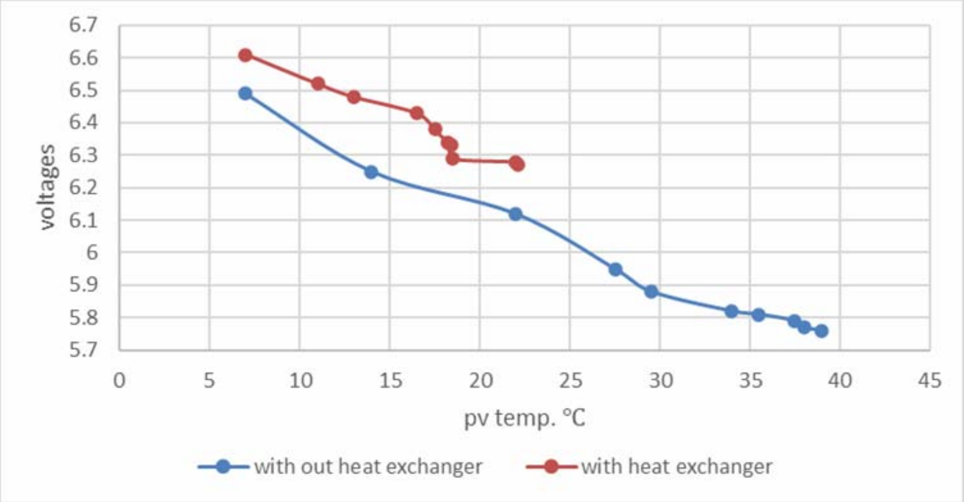

Fig. 3. The voltage changes with the solar cell temperature (with and without heat exchanger)

Conclusions

1. When the heat exchanger is used to cool the solar cell, the cell works more efficiently than if it were without the heat exchanger at the same conditions.

2. If the exchanger is designed according to the specifications of the solar cell or an air source is added (effective cooling), the solar cell efficiency will be higher and thus better performance.

3. When experimenting using the heat exchanger, the rate of heat gain (ΔT = 1.81°C**)** and is considered less than the rate of heat gain without the heat exchanger (ΔT = 3.2°C**)** due to the effect of changing the conditions surrounding the cell.

4. We get higher efficiency and reach a state of thermal equilibrium, which means they work a lot at constant temperature Solar cells and open-circuit voltage stability.

5. The efficiency of the cell has been raised through the heat exchanger and the use of a low-cost cooling fluid, which is water, compared to other high-cost cooling methods [28].

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Повышение эффективности солнечной батареи с помощью теплообменника

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Одной из проблем, возникающих при выработке возобновляемой энергии с использованием солнечных батарей в Ираке (Багдаде), являются высокие температуры наружного воздуха. Из-за свойств кристаллического кремния, используемого в производстве солнечных элементов, на электрические характеристики солнечных панелей сильно влияет температура рабочей поверхности кремниевых солнечных элементов, что приводит к уменьшению энергии, вырабатываемой этими элементами, из-за высокой их температуры. Кроме того, чтобы контролировать снижение нагрева, солнечные панели необходимо охлаждать с помощью теплообменника, в котором в качестве хладагента используется вода. Метод теплообменника потенциально может повысить эффективность солнечной батареи за счет использования отработанного тепла, образующегося во время фотоэлектрического процесса. Это тепло может быть уловлено и использовано для предварительного нагрева воды, которая затем проходит через теплообменник, передающий тепло наружу. Это может повысить общую эффективность солнечного элемента. В настоящем исследовании медный теплообменник использовался для охлаждения солнечного элемента и изучения влияния этого метода охлаждения на температуру и эффективность работы фотоэлектрического модуля. В качестве источника света и тепла использовалась галогеновая лампа. Результаты показали увеличение температуры солнечного элемента, при этом напряжение холостого хода уменьшалось, но при использовании теплообменника температура элемента росла медленно, поэтому напряжение холостого хода уменьшалось. Это происходило гораздо медленнее по сравнению с первым случаем за тот же период, вследствие чего КПД фотопреобразователя не падает, поэтому фотоэлемент работает с более высоким КПД и дает более высокую выработку электрической энергии.

Ключевые слова: солнечные батареи, фотоэлектрические системы, охлаждение, теплообменник, теплопередача.

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