Using Cooling System for Increasing the Efficiency of Solar Cell

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Abstract

According to future predictions, reliance will be largely on solar panels to provide electrical energy. Given its importance, the factors that maintain or increase its efficiency must be studied. Among the factors that reduce its efficiency are temperature, shade, dust and many others. The effect of the temperature on the performance and efficiency of a photovoltaic (pv) panel is one of the main important facing the renewable energy, especially in hot regions, e.g. South part of Iraq. The high temperature to which the pv module is exposed in hot weather reduces the open circuit voltage and the efficiency. In this work, use two methods for cooling, namely water cooling and air cooling. The first method of cooling was air cooling by using dc fan that placed in the back of pv module. While the second method water cooling divided in two techniques, the first technique done by using two pieces of aluminum for cooling (water cooling blocks) placed in the rear of pv module and the second technique of water cooling by using copper perforated tube for spraying water placed in the front of pv module. The average of experimental results shows that the use of technique spraying water cooling are highest enhancement in efficiency than others techniques (water cooling blocks and dc fan) and more effective at high pv temperatures.

Keywords: pv module, water cooling, air cooling, dc fan, water cooling blocks, spraying water, solar cell.

INTRODUCTION

Renewable energy has a wide spread and a great need due to population growth and the need to have a clean and environmentally friendly energy source. Solar energy is the most important and widespread renewable energy, because it is available and sustainable energy [1]. Due to the availability of solar energy, it must be used because if this energy is not used, it will be wasted in the processes of absorption and reflection in the atmosphere. Its quantity is estimated to be twice what it can get from all non-renewable energy sources [2]. Despite the usefulness of solar cells, they only constitute 1% of the current electrical energy production, according to a study conducted in 2007 [3]. PV cell is a device that using for converts the solar energy to the electrical energy by photovoltaic effect when the radiation of sun falls on it. About 80% of the solar energy falling on a PV panel is converted into heat and the rest less than 20% is converted into energy that is used to provide electricity [4]. Sometimes the climate conditions are very hot, as Iraq climate during summer, this leads to a significant rise in the temperature over 55°C of the PV panel, leads to the deterioration of the energy production of the panel to an irreversible condition. The thermal energy accumulates and increases the operating temperature of the PV panel. The efficiency of the solar panel decreases by the amount of the thermal coefficient, which varies among (0.3% and 0.5%) depending on the type of the panel. The rise of one degree of temperature leads to a decrease in the efficiency of the PV panel according to this coefficient. The two researchers (N. Suwapeat and P. Boonla)
discovered that the non-amorphous silicon PV panels have higher efficiency than the crystalline silicon PV panels when operating the panel in high thermal conditions. An increase of 10˚ in temperature reduces about 5 watts of the energy produced [5].

The PV panel is manufactured under standard envelope at 25 °C. If it rises above this level, the performance of the panel will decrease. The effect of this appears on the parameters of the solar panel in general, but the most factor affecting the temperature is the open circuit voltage \((V_{OC})\), which drops negatively whenever the temperature of the panel rises, although a slight increase occurs in the short circuit current \((I_{SC})\) [6]. The effect of temperature on the performance and efficiency of the PV system is very clear and has been proven theoretically and practically in many previous researches. In some studies, it was found that the solar cell decreased in efficiency from 7.2 to 5.6 in 108 days and a loss per day of 0.21%, which was improved by the rain water then the solar system improved and its efficiency returned to approximately 7.1% by Mejia et al. [7] And studied the mechanism of the PV panel cooling system by using DC fan. This system had been developed depending on forced air convection DC fan and the position of the fan in the back side of the panel. The average panel temperature was calculated before and after the fan was installed on the PV panel, the results were evaluated according that. The fan reduced the temperature and thus maintained the performance of the PV panel efficiently by Amelia et al. [8]. Bahaidarah et al. [9] found that when using water cooling system in the back surface of the PV panel the temperature decreased significantly to about 20% and the efficiency of the panel increased by 9% at hot climatic condition like the climate of Dhahran, Saudi Arabia. And Milind et al. reported on the enhancement of a polycrystalline solar panel by using free flow front water cooling system. The area of the solar panel was 60cm * 60cm and the load attached to this panel. They took panel readings and measured voltages and current every 15 minutes 11:00 am to 2:00 pm for a period of five days and at the end the rate was calculated before and after cooling system. The conclusion was increased the efficiency 14.15% during the specific period. The goal here was to cool down and extend the life of the cell to achieve the best work efficiency [10]. The researcher Hachicha et al. [11] in the UAE used both methods at the same time, i.e., front surface cooling by spraying with water and back cooling by water contact directly at the back of the PV module the result was an 11% decrease in temperature. There are many researchers conducting their experiments on this topic. The purpose of this research is to cool the photovoltaic module and keep it from reaching a state of damage that cannot be repaired after, hence its longevity.

**EXPERIMENTAL DETAILS**

A monocrystalline solar module is used of area (36cm * 30cm). The reading of maximum power taken by the indicator to measuring the current and digital multimeter to measure the voltage. Solar power meter (TES 1333R) to measure solar radiation, infrared thermometer -50˚C- 550˚C (-58˚F- 1022˚F) to measure a temperature of the PV module. And the efficiency was calculated using the following formula.

\[
\eta = \left( \frac{P_{MAX}}{A \times E_{STND}} \right) \times 100\% \quad [12]
\]

Where: \(P_{MAX}\): maximum power point, \(A\): area of the solar cell and \(E_{STND}\): irradiance solar cell at standard condition.

From changing the value of the variable resistance, the current and voltages are produced and they are read from the devices, therefore from it the maximum power is calculated with solar radiation and the area of the PV module these applied in the efficiency above formula. Figure (1) shows how the steps for calculating efficiency in practice in measuring devices.
The cooling methods used in this research are:

**1- Air cooling**

Air cooling (rear cooling) used DC fan technique done by installing the fan (12 volts) at the rear of the PV module which is reduce the heat and make its temperature near to the weather temperature and as shown in Figure (2).

**2- Water cooling**

Two water cooling (front cooling and rear cooling) techniques were used as follows.

   **a- Water cooling blocks**

   Two of aluminum block have two openings to exchange and transfer water through them and they installed in the back side of the PV module as shown in Figure (3). The water is delivered to them through water tank that contain a pump to lift the water in a closed circulation. The closed cycle is represented by exchanging water from the tank, which raises the water to the first cooling water block and to the second cooling water block through nylon tubes, then reaches the water to the water tank again with its pump that raises the water, and so on to repeat its work again until the closed internal cooling process is completed.

   **b- Spraying water cooling**

   The cooling process in this technique is done by a perforated copper tube installed in the front surface of the PV module and as shown in figure (4). And it is illuminated by a closed circulation of water through two tanks containing a pump to raise the water and nylon tubes as above technique to deliver the water to the copper tube that sprinkles water on the surface of the module. This technique includes a filter to filter the water after the spraying process, as the resulting water is loaded with dust and dirt that formed on the surface of the module as a result of the atmospheric effects. This technique is considered to be cooling and cleaning the PV at the same time.

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**Figure (1) Schematic diagram of measuring efficiency**
The above three technologies used in the methods (water cooling and air cooling) are supplied with electricity to work by means of a battery (12 volt). The battery is charged periodically whenever it is exhausted by the battery charger.

The most important test in this paper is to measure the temperature of the PV, which determines whether the module needs to be cooled or not. The average ambient temperature during the test days is 35 °C. The calculation was made in March, April and May of the weather in Nasiriyah, Iraq, from 9 am to 5 pm under solar radiation appropriate to the time in which they were measured. All measurements were at tilt angle of 33°.

RESULTS AND DISCUSSION

The effect of the three cooling technologies, represented by DC fan, blocks, and spraying water were investigated. Each of them had a difference in their installation location and the degree to which they enhanced the efficiency and reduced the PV temperature, as mentioned above. Four measurements were made, the first was before the cooling process, and the results are as in Table (1), which show the effect of solar radiation and PV temperature on the power and efficiency of the PV module.

| Time (hours) | Solar irradiance (W/m²) | PV Temperature (°C) | P_MAX (W) | Efficiency % |
|--------------|-------------------------|---------------------|-----------|--------------|
| 9:00-10:00   | 620                     | 54.6                | 6.84      | 10.22        |
| 10:00-11:00  | 735                     | 58.3                | 7.48      | 9.42         |
| 11:00-12:00  | 850                     | 64.2                | 8.14      | 8.86         |
| 12:00-13:00  | 980                     | 68.3                | 8.37      | 7.9          |
| 13:00-14:00  | 1050                    | 71.5                | 8.57      | 7.56         |
| 14:00-15:00  | 835                     | 63.6                | 8.04      | 8.91         |
| 15:00-16:00  | 760                     | 59.7                | 7.62      | 9.28         |
| 16:00-17:00  | 570                     | 52.9                | 6.37      | 10.34        |

The highest average temperature of the PV during the measurement days was recorded at 71.5 at 1 pm. The results of the remaining three measurements are obtained from the use of the three cooling techniques in the process of improving efficiency.

1- Air cooling (DC fan)

The DC fan works as a technique for the air-cooling method which that by removes the hot air, which makes PV hot and replaces it with cold air because the density of cold air is higher than that of hot air, which cools the module from the external environment and makes it very close to the ambient temperature. Table (2) show the results of using DC fan for cooling and notice the clear decrease in the module temperature more than 16 °C which represented by the percentage temperature of 26.24%, causing an increase in the average percentage efficiency of the PV by 9.34%. Hence, the temperature in module is lower than before and then cooled down, thus enhancing it. To ensure complete cooling of the
PV, fans must be provided that completely cover the module. In this experiment a single DC fan was sufficient due to the small size of the module used for the test.

### Table (2) Daily average with DC fan cooling

| Time (hours) | PV Temperature (˚C) | P<sub>MAX</sub> (W) | Efficiency % |
|--------------|---------------------|---------------------|--------------|
| 9:00-10:00   | 38.3                | 7.58                | 11.32        |
| 10:00-11:00  | 42.2                | 8.25                | 10.39        |
| 11:00-12:00  | 48.3                | 8.94                | 9.73         |
| 12:00-13:00  | 52.6                | 9.2                 | 8.69         |
| 13:00-14:00  | 55.8                | 9.44                | 8.32         |
| 14:00-15:00  | 47.7                | 8.84                | 9.8          |
| 15:00-16:00  | 43.6                | 8.37                | 10.19        |
| 16:00-17:00  | 36.6                | 7.12                | 11.56        |

Compared to other research that used the same technique to cool a large PV panel, a decrease in panel temperature was obtained from 59.88 °C to 53.64 ° and forms a percentage 10.42% [8].

#### 2- water cooling

The water temperature used in both techniques of water-cooling is between 15˚C and 20˚C, which is much colder than the PV temperature in order to draw heat from the surface and back of the module to complete the cooling process which achieve the required module enhancement.

##### a- Cooling blocks

The using of aluminum water cooling blocks technology, results were obtained as shown in table (3). The cooling process was different from one area to other for the same module where the block is adjacent to its back surface of it is colder than others. the process of reducing the PV temperature resulting from this technique is 9.3˚C and a percentage reduction equal to 15.4% then the increase average percentage of efficiency was by 5.65%.

### Table (3) Daily average with water cooling blocks

| Time (hours) | PV Temperature (˚C) | P<sub>MAX</sub> (W) | Efficiency % |
|--------------|---------------------|---------------------|--------------|
| 9:00-10:00   | 44.7                | 7.27                | 10.85        |
| 10:00-11:00  | 48.6                | 7.93                | 9.98         |
| 11:00-12:00  | 55.1                | 8.6                 | 9.36         |
| 12:00-13:00  | 59.9                | 8.85                | 8.36         |
| 13:00-14:00  | 63.4                | 9.08                | 8.01         |
| 14:00-15:00  | 54.7                | 8.5                 | 9.42         |
| 15:00-16:00  | 50.1                | 8.05                | 9.8          |
| 16:00-17:00  | 42                  | 6.82                | 11.08        |

The temperature of the PV panel was lowered by cooling the back of it with the cooling water. An efficiency increases of 9% was recorded in the hot conditions of the Saudi climate [9].

##### b- Spraying water

Table (4) shows the results of cooling with the technique of spraying water cooling, which draws heat from the front surface of the PV, causing cool it down to raise the energy productivity, which increases as the water is colder and spraying for a longer period, and this greatly increases the efficiency of the module and the increase is according to the measurement here was 11.89%. The rates were 21 and 34.43% reduce in the PV temperature and percentage temperature respectively.
Table (4) Daily average with spraying water cooling

| Time (hours)       | PV Temperature (˚C) | P\(_{\text{MAX}}\) (W) | Efficiency % |
|-------------------|---------------------|-------------------------|--------------|
| 9:00-10:00        | 32.3                | 7.81                    | 11.66        |
| 10:00-11:00       | 37.1                | 8.49                    | 10.69        |
| 11:00-12:00       | 43.8                | 9.19                    | 10.01        |
| 12:00-13:00       | 48.6                | 9.46                    | 8.93         |
| 13:00-14:00       | 51.9                | 9.71                    | 8.56         |
| 14:00-15:00       | 43.1                | 9.09                    | 10.07        |
| 15:00-16:00       | 38.3                | 8.61                    | 10.48        |
| 16:00-17:00       | 30.6                | 7.34                    | 11.92        |

When using a free flow front water cooling system on a PV module at noon time for five consecutive days the increase in efficiency was 14.15% [10]. Figure (5) shows the impact of the average PV temperature on efficiency during the times of the hot days of months in which the study was conducted before and after the use of cooling techniques.

Figure (5) Daily average efficiency and temperature of PV

When solar irradiation increases, this leads to the drop in the output voltage due to the increase in the PV temperature with the increase in solar radiation whose energy is higher than the band gap of the semiconductors. The opposite of the effect of solar radiation increases the output current. And because of the decrease in the output voltage of the cell, it will lead to a decrease in the electrical energy produced, and thus reduce the efficiency with increasing solar radiation.
CONCLUSION
The need for cooling mechanisms that enhance the efficiency of the PV module appears when the event that the temperature of the PV exceeds the reasonable limit, i.e. more than 45 ° C, it will lead to a decrease in the electric energy produced. To solve this problem, two methods of cooling were used, namely air cooling and water cooling, which work to draw heat from PV to reduce its temperature, which decreases the output voltage despite a slight increase in the output current. When using cooling technologies, there is an increase in the amount of electrical energy produced, which increases the efficiency of PV depending on the amount of solar radiation. The DC fan, used as an air-cooled method, lowered the temperature of the module by more than 16˚C and increased its efficiency by 9.34%. As for the water-cooling method, the PV temperature was reduced to 9.3˚C and 21˚C for both cooling techniques (blocks and the spraying) respectively, and the average percentage efficiency increased by 5.65% and 11.89 for the same sequences of water-cooling process. It was concluded that the best method used to enhance the efficiency and the most suitable for hot climates is the spraying water technique for cooling.

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