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Study the effect of Environmental Factors on the Efficiency of Photovoltaic Module

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Abstract

The effects of various environmental factors have been studied on the efficiency of the PV module as an essential part of the work and how to enhance its efficiency by reducing the influences environmental factors. The study deals with the efficiency of PV module and how to calculate and improve them. The measurements were made from December 2020 to August 2021 at 9 am to 5 pm for the weather of the city of Nasiriyah. The examination a single PV module is used, which gave an P_{MAX} equal to 10 Watt. The most important has been studied on the PV is the temperature, whenever its grateful that led to decline in the output voltage and slight decrease in the output current. The output current PV module increased when the rise in the solar irradiance. To mitigate the impact of this factor, air cooling and water cooling had been used through cooling techniques by using DC fan, cooling blocks and water douche. It is clear that from our work we have improve efficiency of the module during the hot weather by 18% from using (air cooling and water cooling) techniques together. For another factors, such as dust, shadow, and exhaust smoke, showed factors no less an important factor should be besides temperature. The greater the quantity of these effects on the surface of the PV module, the more reduce in its efficiency. The influence of these factors appears to significantly reduce the output current due to its blocking of solar irradiance from PV module led to drop in the output voltage.

Keywords: PV module, Temperature, DC fan, Cooling blocks, Water douche, Dust, Shadow, Car exhaust smoke.

الخلاصة: تم دراسة تأثير العوامل البيئية المختلفة على كفاءة اللوح الكهروضوئي كجزء اساسي من العمل وكيفية تحسين كفائته من خلال تقليل تأثير هذه العوامل. وتناول البحث كفاءة الوحدة الكهروضوئية وكيفية حسابها وتحسينها. اجرينا القياسات ابتداءا من شهر كانون الاول ٢٠٢٠ ولغاية شهر أب ٢٠٢١ من الساعة ٩ صباحا وحتى ٥ مساءا لطقس مدينة الناصرية. تمت الفحوصات على لوح شمسي ذي قدرة (١٠ واط). واهم عامل تم دراسة تأثيره على اللوح الشمسي هو درجة الحرارة حيث لاحظنا كلما ازداد تأثيره ادى ذلك الى انخفاض في الفولتية الناتجة وانخفاض بسيط في التيار الناتج الذي يزداد بأرتفاع الاشعاع الشمسي. لتقليل تأثير هذا العامل قمنا بأستخدام طريقتي تبريد الهواء وتبريد الماء من خلال ثلاثة تقنيات وهي مروحة التيار المستمر، بلوكات التبريد ودوش الماء. تبين افضل تقنية لتحسين كفاءة االوحدة الكهروضوئية هي استخدام تقنية الهواء والماء معا التي اعطت زيادة في الكفاءة خلال الطقس الحار بمقدار ١٨%. لعوامل اخرى مثل الغبار والظل ودخان عادم السيارة اهمية لا تقل عن عامل درجة الحرارة. كلما زادت كمية هذه المؤثرات على سطح اللوح الشمسي ادى ذلك الى نقص في كفائتها. يكون تأثير هذه العوامل على تيار الخرج كبير بسبب حجبه الاشعاع الشمسي من الوصول الى اللوح وبالتالي يؤدي الى جهد الخرج الناتج.

1. INTRODUCTION

Solar energy is a free resource available in nature at times of the day, so it can be used due to the abundance of energy it produces. The amount of solar energy that it generates in an hour is estimated to be greater than the energy consumed by mankind for a whole year, and it is estimated twice what can be obtained from all non-renewable energy sources [١]. The solar cell is one of the most important devices through which you can exploit

this energy as it converts it into energy workable electric [2, 3]. The first advanced solar cell made of semiconductor silicon, which has the ability to absorb photons from the sun, was done in Bell Laboratories and later became a high conversion efficiency of up to 24% [٤] [٥]. The consumption of renewable energy varies from place to place and according to its development and level of economic development, so the developing countries decided to rely on this energy by 20% in 2020 and to become a final` electrical source by 2030 to reduce dependence on non-renewable energy sources that cause harmful global warming in the atmosphere air [6]. The temperature factor is considered the most influential factor on the performance of the panel, and its negative effect appears on the output voltage and slightly on the output current, depending on the strength and time of the solar radiation. About 80% of the solar energy when it falls on the photovoltaic unit turns into heat, and only about 20% can be used to provide electricity [6-8]. PV cell cooled by two techniques DC water pump and DC brushless fan reported by Irwan et al. [9]. They compared the results between the two technologies, and the result was a decrease in the temperature of the panel 6.36 at using a water pump, while the temperature decreased by 6.1 when using the fan. The improvement of a solar panel by using free flow front water cooling system reported by Milind et al. [10]. They took a 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 raising the efficiency 14.15% during this period. Another study to improve the efficiency of the solar modules after being exposed to a high temperature. Researchers Rakino et al. [11] found a cooling mechanism resulting from a water cooling and heat sink cooling techniques. This way results were a significant decrease in temperature to more than 40% which led to a high enhancement in the efficiency of the panel. Dust is defined as fine solid particles that have a very small diameter which accumulating 4 grams per square meter of dust reduces efficiency by 40%. Its causes are many, including the winds that carry it from distant areas and others, and it has been studied in many researches, according to different regions . Gupta [12] showed in his study that the panel if not cleaned from the air dust and dirt every month, its performance drops more than 20%. While the researcher Salim A et al. [13] found that the power generated from a solar array is reduced by 32% if it is not cleaned for 8 months, but when rainwater came it was cleaned the dust loaded solar cells and the resulting energy shortage became only 2%. Khadhim et al. The result was that the first panel remained preserving its good efficiency. The remaining panels with weekly and monthly cleaning and non-cleaning, their efficiency reduced (7.9%, 20% and 27%) respectively. As for the shadow performance is affected by its various types, regular, irregular, emanating from the cloud, partial and complete [14, 15]. Sathyanarayana et al. [16] showed a study on the effect of shade on the efficiency and power of solar panels. The result was that when the shadow was present, it gave a variable behaviour according to the type and amount of shadow on the panel, and all of them reduced its performance. To enhance panel efficiency, avoid panel making under shading conditions [17]. In this work, the purpose is to discuss the effect of dust, shade and car exhaust on the efficiency of the PV panel and how it can be after the improved by removing the influencing factor. The benefit of this experience is to reduce the degradation of the PV panel's efficiency and thus its longevity.

2. OBJECTVE AND PURPOSE

In this study, the effect of several factors affecting the efficiency of the solar cell (temperature, dust, shade and car exhaust smoke) was investigated during the period from December 2020 to August 2021 as following:

1- Temperature is the most important factor effects on the PV and handled or control it by two methods (air and water) cooling.
2- Discuss the effect of dust, shade and car exhaust on the efficiency of the PV module and how it can be after the improved by removing the influencing factor.
3- Reduce the degradation of the PV panel's efficiency and thus its longevity.

3. METHODOLOGY AND PROCEDURE

In this study used some device to measuring the efficiency of the PV module as following:

1- infrared thermometer -50˚C- 550˚C (-58˚F- 1022˚F) to measure a temperature of the cell and the temperature is measured from the front surface module.
2- Solar power meter (TES 1333R) is used to measure the solar radiation.
3- The value of the current, voltage (maximum power point),V_{OC} and I_{SC} are obtained by using a small resistance (rheostat = 318 ohm), an indicator to calculate the current value, and a digital multemeter to measure the voltage value.

Power efficiency is the ratio of output power to the input power of the solar cell as shown in formula 1 [10].

$$\eta = \left(\frac{P_{out}}{A * E_{STND}}\right) * 100\% \quad (1)$$

η: Efficiency of solar cell.
P_{out} : Output power of solar cell.
A : Area of solar cell.
E_{STND} : Solar irradiance under STC

The calculation is done by changing the value of the rheostat and in each change a value is obtained for the voltage shown in a screen of digital multimeter and the current in the screen of indicator device. From V_{OC} and I_{SC} are produced directly from the PV module with using a digital multemeter as shown in figure 1 which represents an schematic of action steps to measure efficiency.

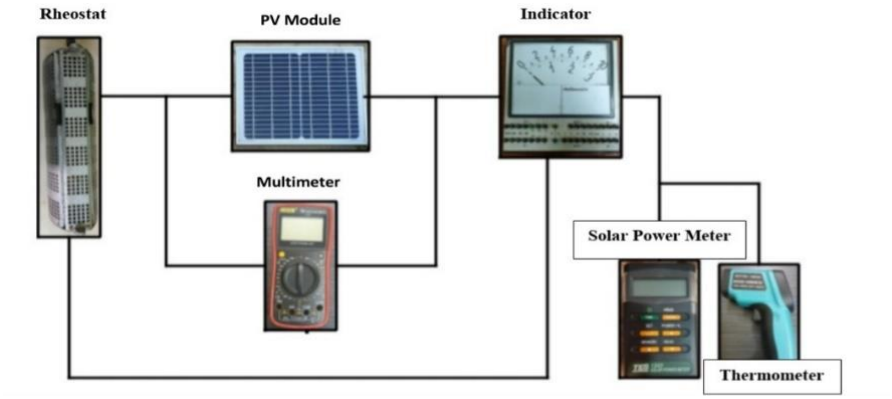

Figure 1. Efficiency calculation steps chart.

4. COOLING PV SYSTEM

The cooling PV system consists of three techniques resulting from two cooling (air and water) methods, which are as follows:

4.1.DC fan

DC fan (12 volt) used as a process of air cooling method which was installed in the back of the PV module, as shown in figure 2. The benefit of the DC fan is to removes the hot air away from PV and convert its heat close to the ambient temperature. Hence, the temperature of the module is lower than before.

4.2.Water cooling blocks

Cooling technique by water blocks is carried out through an inner tube that acts as a heat dissipator transfers heat from the source to be cooled to the liquid that flows through the water block. Two blocks made of aluminum are installed on the back surface of the PV module as shown in the figure 3 the water is lifted to the blocks installed on the back of the PV by a water tank containing a lift pump. The process is carried out in a closed water cycle by means of nylon tubes. The water moves from the tank to the first to the second block, and then the water returns to the same tank, and so on, the work is repeated again until the closed cooling process is completed.

4.3.Water douche

The cooling process in this technique is done by a copper tube installed in top front surface of the PV module as shown in figure 4. It is illuminated by a closed circulation of water through tank containing a pump to raise the water. And found a nylon tubes to deliver the water to the tube that sprinkles water on the surface of the module. This technique includes a filter to filter the water after the douching process, as the resulting water is loaded with dirt and dust that on the surface of the PV as a result of the weather effects. This technique is considered a cleaning and cooling the PV in the same time.

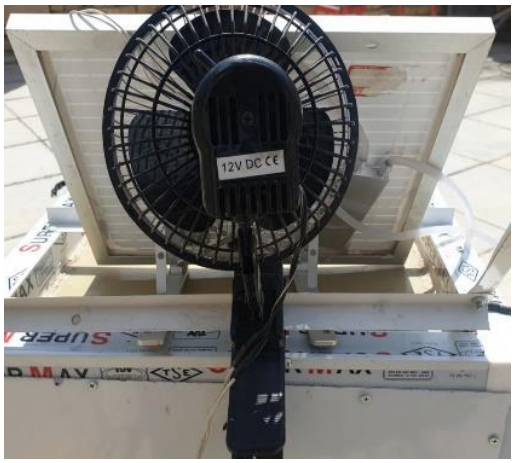

Figure 2. DC Fan

Figure 3. Cooling Blocks

Figure 4. Water Douche

5. PV MODULE EFFICIENCY WITH TEMPERATURE EFFECT

When the PV module heats up, the current rises slightly and the voltage drops dramatically according to the solar irradiance, so the maximum power (P_{MAX})and efficiency are less effective. Table 1 show the average Calculations with and without enhancement techniques when effects on hot days of the weather months that extended from March to Augest at 1 pm with solar irradiance 1050 Watt/m^2.

Table 1. Effect of temperature with and without enhancement techniques

Module Cooling Techniques	Decrease in Temperature (˚C)	P_{MAX} (W)	Increase In Efficiency (%)
Without	73.8	8.21	7.24
Dc fan	58..1	9.17	8.08
Cooling Blocks	63.7	8.75	7.71
Water Douche	51.2	9.59	8.45
Air and Water	46.5	9.76	8.6

Bycomparing in the obtained results with the previos methods we can calculate that the best tecnique to obtain the optimum power and efficiency of the PV module using air and water cooling method. DC fan technoque reduced the PV temperature by 16.9˚C and the efficiency improvement amount was 11.78%. As a comparison with the previous study has been proposed by [9],[18]. From water cooling blocks we got 10.7˚C in PV temperature led to increase in efficiency to 7.03%. A 9 ˚C that studied by [19, 20] when using similar technique. From the above results of water douche technique, we got 23.89˚C oriented in module temperature led to increase in efficiency to 16.2%. Similar to the ways reported by [21] [22] [10]

6. PV MODULE EFFICIENCY WITH DUST EFFECT

The P_{MAX} and efficiency of the PV were calculated when exposing it to a light, heavy amount of dust. After that, it was manually cleaned and the results were shown below in the Table 2. The measurement made at 10 am in the november with different solar irradiation. When the amount of dust on the surface of module increased led it to a large decrease in the output current with low reduce in the output voltages due to its large blocking of solar irradiation.

Table 2. Effect of dust on PV efficiency

Amount of Dust on PV	Solar irradiance (W/m^2)	P_{MAX} (W)	Efficiency (%)
Little	710	6.92	9.02
Heavy	695	2.58	3.34
Cleaning PV	690	8.63	11.58

The values of efficiency increased from low value at study time for dusty module to high value for clean module. Similar observation has been reported by Mejia et al. [23].

7. PV MODULE EFFICIENCY WITH SHADOW EFFECT

Shade is one of the most famous factors that affect the performance of the solar cell , as its effect appears by reducing the amount of PV output power produced as a result of the large drop in its current when there is no sun that provides power to the system. The study were to some rates that are 25%, 50% and 100%, as shown in Table 3. The calculation were done and the results were obtained at 12 pm in the Decemper at different irradiance according to measurements time. It was shown that with increasing shade by 25%, the P_{MAX} reduces by about 2.5%.

Table 3 Effect of shadow on PV efficiency.

Type of Shading	Solar irradiance (W/m^2)	P_{MAX} (W)	Efficiency (%)
No Shading	915	9.27	9.38
Tree	920	7.77	7.82
Building	930	5.08	5.05
Cloud	167	0.86	4.76

When the greater the amount of shade, the lower the efficiency of the PV module according to behavior of shadow [24]. Likewise, the effect of cloudiness greatly reduced its output energy and efficiency on PV panel [25].

8. PV MODULE EFFICIENCY WITH CAR EXHAUST SMOKE EFFECT

Another important environmental factor have an influence on PV, so car exhaust smoke also has an effect. According to future expectations, the PV cells will be completely provide the electrical energy instead of fossil energy sources, as the PV module will be placed in all places, and among these regions are the auto stations that generate harmful smoke. Smoke has an effect that varies according to its amount on the PV surface. The higher its concentration, the more it leads to a reduce in the current and voltage.Table 4 represents the calculations of this factor with varios amount (light, medium, heavy and without) of it. The measurements were obtained at 11 am in the January.

Table 4 Effect of temperature with and without enhancement techniques.

Amount Car Exhaust smoke	Solar irradiance (W/m^2)	P_{MAX} (W)	Efficiency (%)
Without	835	8.38	9.29
Light	840	7.71	8.5
Medium	830	5.9	6.58
Heavy	825	3.46	3.88

Figure 5 shows a flow chart of studies factors effects of the efficiency of PV module that were at 1 pm.

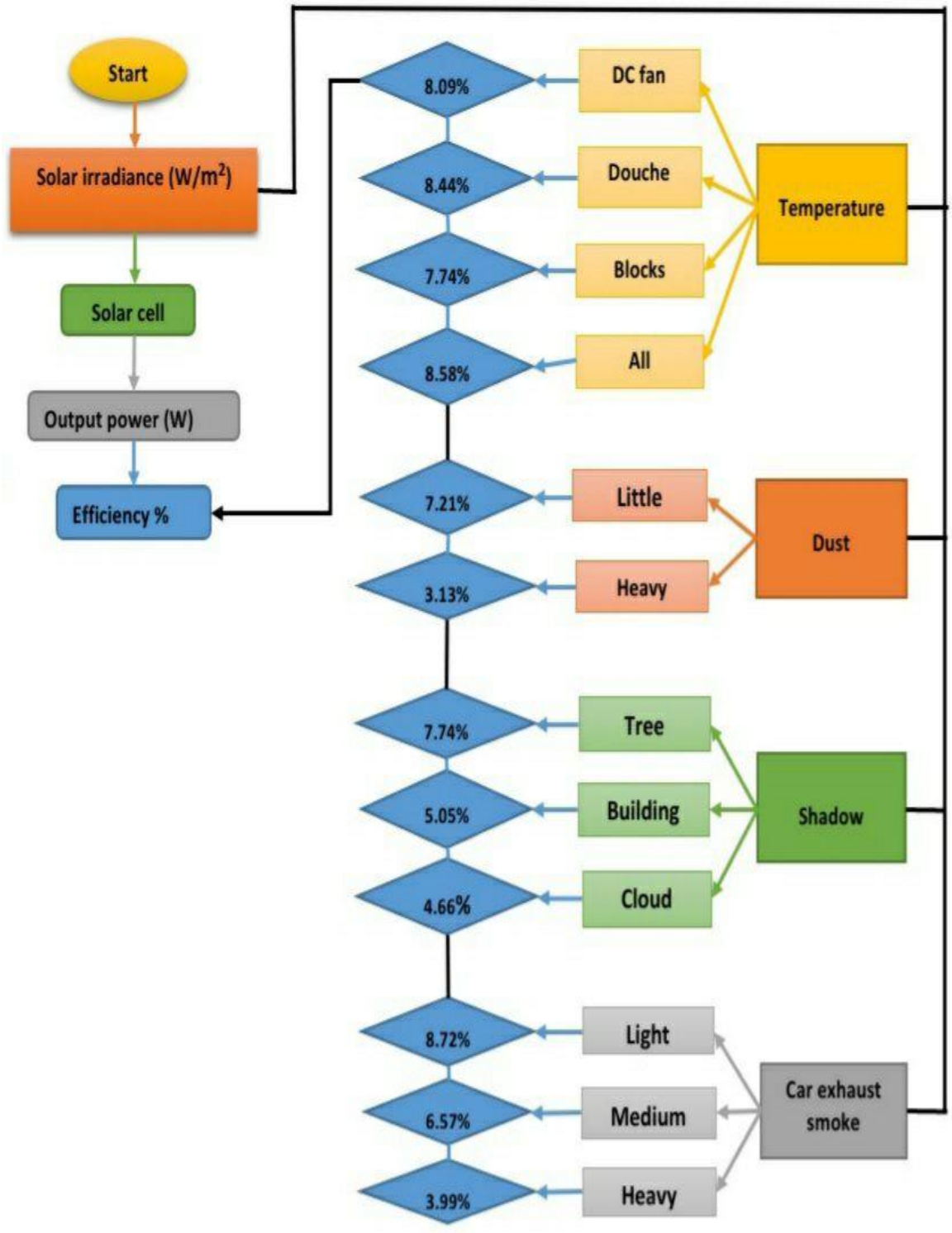

Figure 5. Flow chart for PV efficiency with effect factors at 1pm.

For future work conduct a similar study that includes other factors for photoelectric improvement, in addition to applying another study that includes different measuring devices such as the use of nanotechnology and other devices that fit the current environment.

9. CONCLUSIONS

PV converts solar energy into electrical energy and due to its importance and usefulness, in addition to being cheap and available. The aim at this work is to enhance the efficiency of the PV module after controlling the environmental factor that effects on module in the hot climate of the city of Nasiriyah. The temperature factor affects the module a lot as it does not work efficiently when the cell exceeds the temperature of 45˚c due to the voltage drop significantly. Two cooling methods were used to improve the efficiency of the cell, namely, first method is done by dc fan technique installed at the back of the cell. The temperature has got reduction up to 17˚c and an increase in efficiency of 11.88% has been obtained. The second method is done by using the two cooling blocks technique, installed at the back of the cell and the water douche technique installed on the top of the PV to spray water on the front surface. The cooling method was carried out in a closed water cycle by means of a tank containing a pump to raise water by tubes and filter to clean the water after exposed it to dust and dirt produced from environmental effect. The best results were obtained using (air cooling and water cooling) techniques to obtain a clear cooling of the module is with the water douche technique, where the temperature decreased by 41.06% and the efficiency increased by 18%. The effect of dust and shadow factors showed the reduces were similar to the temperature effect when its quantity is increased on the surface of the pv module. This thesis presented the various cooling methods to keep the efficiency of a pv in the accepted work levels.

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