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The effect of cooling on the PV solar panels performance: An experimental approach

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capacity

Abstract

The efficiency of the solar panel is one of the characteristics that researchers seek to increase and improve. The heat of the solar panel resulting from sunlight falling on it is one of the reasons affecting the efficiency of the solar panel, which causes it to decrease. In our paper, we conducted a comparison experiment between two panels, the first without cooling and the second with cooling. We prepared the solar panel by placing tubes behind the solar panel. The tubes were copper and 5 meters long, and we crimped them so that the distance between the twisted tubes was 13 cm. We installed a temperature sensor at the water entry point and also at the water exit point. Another on the surface of the solar panel, and for the panel without cooling, the temperature was measured using a thermometer after adjusting and adjusting it. When we ran the experiment, the decrease in the temperature of the photovoltaic surfaces was about 5 degrees Celsius, while the average temperature of the solar panel with cooling was 37 degrees Celsius and without cooling, 42 degrees Celsius. The electrical power also increased by 5 watts. The system efficiency was 81%, meaning it increased by 4%. The maximum value of solar radiation was 945 w/m2, and the ambient temperature was 21°C, while the temperature of the solar panel was 45.7°C. The paper concluded that cooling has an effective effect in increasing efficiency, with greater attention to accuracy in design.

تأثير التبريد على أداء الألواح الشمسية الكهروضوئية: منهج تجريبي"

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الملخص

كفاءة اللوح الشمسي من الخصائص التي يسعى الباحثون لزيادتها وتحسينها، وتعتبر حرارة اللوح الشمسي الناتجة من سقوط أشعة الشمس عليها، أحد الأسباب المؤثرة في كفاءة اللوح الشمسي، مما يسبب في تناقصها. ونحن في ورقتنا أجرينا تجربة مقارنة بين لوحين، الأولى من غير تبريد والثانية بالتبريد، حيث جهزنا اللوح الشمسي، وذلك بوضع أنابيب خلف اللوح الشمسي، وكانت الانابيب من النحاس وطولها 5 متر، وقمنا بدعجها بحيث كانت السافة بين الانابيب الملتوية 13 سم. وقمنا نحن بتثبيت حساس للحرارة عند نقطة دخول الماء وكدلك عند نقطة خروج الماء. آخر على سطح اللوح الشمسي، وبالنسبة للوح بدون تبريد تم قياس درجة حرارة بواسطة جهاز قياس الحرارة بعد تعديله وضبطه. ونحن لما قمنا بتشغيل التجربة كان الانخفاض في درجة حرارة الأسطح الكهروضوئية حوالي 5 درجات مئوية، حيث كان متوسط درجة حرارة اللوحة الشمسية بالتبريد 37 درجة مئوية وبدون تبريد 42 درجة مئوية. وأيضا زادت القدرة الكهربائية بمقدار 5 وات. وكانت كفاءة النظام 81% يعني زادت بمقدار 4%، وكانت أقصى قيمة للإشعاع الشمسي هي **945 w/m2** , ودرجة الحرارة المحيطة **21°C** , في حين كانت درجة اللوح الشمسي **45.7°C** . وخلصت الورقة بان التبريد له تأثير فعال في زيادة الكفاءة مع الاهتمام الأكثر بالدقة في التصميم.

الكلمات المفتاحية:
الكهروضوئية
الماء
التبريد
درجة حرارة لوحة الكهروضوئية

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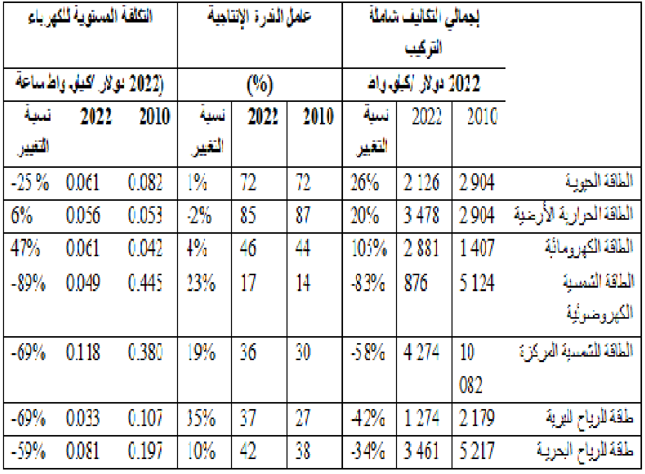
1. Introduction

The fossil fuel price crisis in 2022 is evidence of the attractive economic benefits of renewable energy resources on energy security. In 2022, renewable energy resources deployed globally since 2000 have saved approximately $521 billion in fuel costs in the electricity sector. Given the rise in fossil fuel prices, the years 2021-2022 saw the largest improvement in the competitiveness of renewable energy in the past two decades. Among the most prominent observations that can be deduced by reading energy data since 2010 are the following:

In 2010, the global weighted average levelized cost of electricity for onshore wind projects was 95% higher than the lowest fossil fuel solution; In 2022, the global weighted average levelized cost of electricity for new onshore wind projects was 52% lower than the cheapest fossil-fuel solutions.

•This improvement exceeded the increase recorded in solar photovoltaic energy; This renewable energy source was 710% more expensive than the cheapest fossil fuel-powered solutions in 2010; However, their costs in 2022 decreased by 29% compared to the cheapest fossil fuel solutions, driven by the significant reduction in costs.

Table H.1: Total costs including installation, capacity factors, and levelized cost trends of electricity production by technology type, 2010 and 2022 [1].



	إجمالي التكاليف شاملة التركيب 2022 دولار /كيلو واط			عامل القدرة الإنتاجية (%)			التكلفة المستوية للكهرباء (2022 دولار /كيلو واط ساعة		
	2010	2022	نسبة التغير	2010	2022	نسبة التغير	2010	2022	نسبة التغير
الطاقة الحيوية	2 904	2 126	26%	72	72	1%	0.082	0.061	-25 %
الطاقة الحرارية الأرضية	2 904	3 478	20%	87	85	-2%	0.053	0.056	6%
الطاقة الكهرومائية	1 407	2 881	105%	44	46	4%	0.042	0.061	47%
الطاقة الشمسية الكهروضوئية	5 124	876	-83%	14	17	23%	0.445	0.049	-89%
الطاقة الشمسية المركزة	10 082	4 274	-58%	30	36	19%	0.380	0.118	-69%
طاقة الرياح البرية	2 179	1 274	-42%	27	37	35%	0.107	0.033	-69%
طاقة الرياح البحرية	5 217	3 461	-34%	38	42	10%	0.197	0.081	-59%

In 2022, the global system of solar energy will reach 1,177 GB. This growth in the solar PV market reflects a global transformation towards renewable and sustainable energy technologies. China and the United States lead the global photovoltaic energy market, with a sought of 307 and 122 gigawatts of complex solar solar energy, respectively. On the other hand, Chile and Honduras obtained the highest share of the PV mix in the total energy produced in 2022. [2]. Systems that use solar energy are divided into two categories [3]. A hybrid photovoltaic/thermal solar collector uses solar energy to generate heat and electricity in one integrated system. (Figure 1).

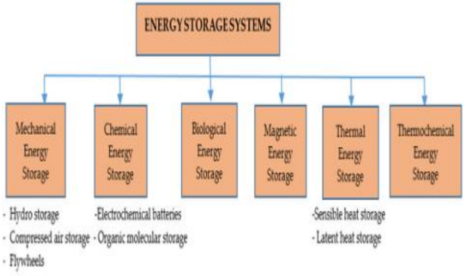


Figure 1. solar energy systems classification

The basic idea behind how solar collectors work is that they require a liquid to pass through an absorber, which may be air, water, or a mixture of liquids. By attaching a heat exchanger to the back of the PV module, solar energy can be simultaneously converted into electrical and thermal energies [4]. This emerging technology for harnessing solar energy is known as a photovoltaic/thermal hybrid collector. Figure 2.

Thermal and electrical energy can be generated simultaneously from solar energy by connecting a heat exchanger to the back of the PV module. A photovoltaic/thermal hybrid collector, called PV for short, is a newly developed technology for collecting solar energy, see Figure.2 [5].

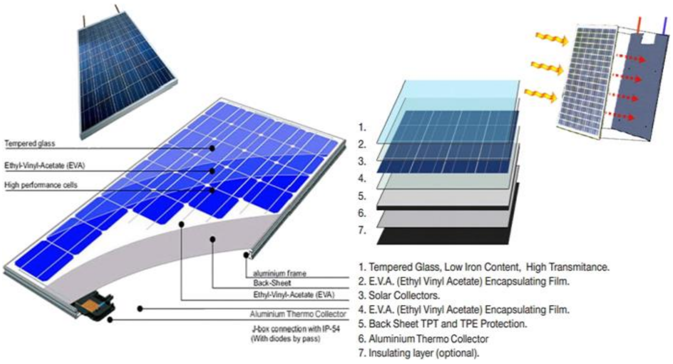


Figure 2 An example PVT system outlining the basic structure for how it collects both electrical (component 3) and thermal energy (component 6). Image from source

The thermal characteristics of the working fluid have a significant impact on the heat transfer process' efficiency. The cost of PV collectors will go down and overall efficiency will rise if new, as-yet-undiscovered fluids with superior thermal properties are used in place of the standard working fluids. This will happen through increased usable heat gain. [6].

Adding Nano fluids to working fluids which are used in solar thermal systems is one of the best ways to enhance their heat transfer properties. To improve its thermal characteristics, mineral nanoparticles are combined with a base fluid which can be water, oil, or ethylene glycol to create Nano fluid [7].

2. LITERATURE REVIEW

One of the most promising technologies to address the energy and environmental issues brought on by the overuse of fossil fuels is the efficient use of solar energy[8]. Converting the wave bands near the ultraviolet and infrared portions of solar radiation into thermal energy and the waves near the visible portion of solar radiation into electrical energy is one method for harnessing solar energy. [9].

Common photovoltaic modules convert 4-17 % of the solar radiation into electricity, depending on the solar cells used. That is, 50% of the incident solar energy is converted into heat. Converting solar radiation into electricity may lead to an increase in cell temperatures of up to about 50 degrees Celsius above ambient temperature. This results in high levels of cell working temperatures[10]:

- Cell efficiency decreases (usually 0.4% per degree Celsius).
- Increased heat stress for a long period of time leads to cell damage.

Electricity production can be improved by cooling solar cells with fluids such as water. Reusing the thermal energy extracted from the chiller is one of the preferred designs in theory. This is why we improve the productivity per unit area of the board. This contributes to the development of hybrid solar technology PVT Figure 3 [11].

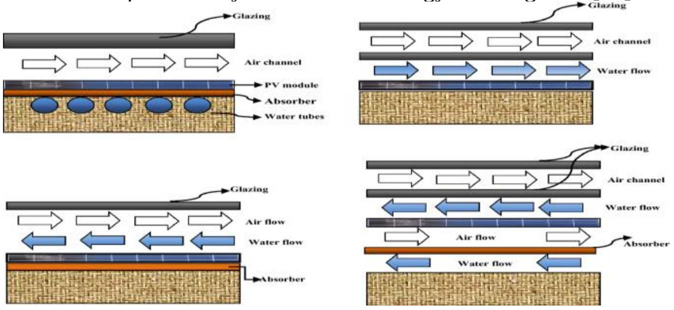


Figure 3 Common designs for flat PV collectors

The liquid outlet temperature, which is between 40 and 50°C, is the highest temperature that can be achieved. It shows that the total thermal energy is suitable for heating homes. As a result, it serves a variety of thermal purposes and provides high-quality thermal energy [12]. This restricts the use of planar photovoltaic systems. This also restricts the realistic scale of the system, as the sensor area required for water or heating is often much smaller than the area necessary for power[13]. We employ solar concentrators with PVT to lower the system's cost by swapping out the expensive photovoltaic module for a big, inexpensive mirror. When the temperature of the PV module is kept low, concentrated photovoltaic systems (CPVs) offer higher efficiency than traditional systems. [14].

The development of the spectral division technique, which divides solar radiation falling on PVT into two parts based on wavelength, allowed PVT systems to be rendered more reliable [15]. Hence, the photovoltaic cell receives that portion of the solar spectrum, while the thermal receiver receives the other portion. The following are the advantages of applying the spectral segmentation method [16]:

- Photovoltaic cells use a portion of the sun's energy to generate electricity. It needs to shield the solar cells from the damaging effects of high temperatures.
- through the thermal unit, a portion of the solar radiation is transformed into Thermal energy. The spectroscopy technique can be proven through two methods:
- Absorption method.
- Reflection method.

The liquid-based filtration method in Figure 4 (a, b) uses a selective absorption operating medium that absorbs UV and infrared wave bands from solar radiation, converts them into thermal energy, and transmits the visible bands to photovoltaic cells to convert them into electricity.

Transport fluid terms and conditions limit the system's photovoltaic performance and maintain reliable conductivity, using air, raw, living and polyethylene glycol transport fluids [17].

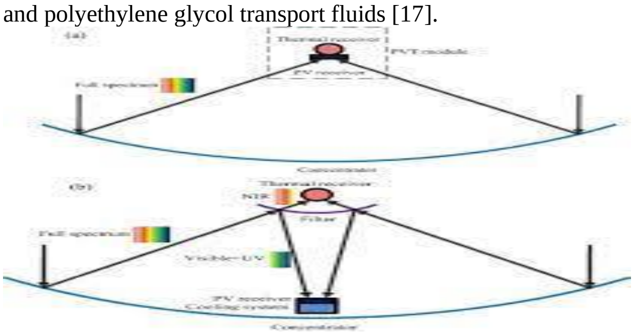


Figure 4 a)Sketch of a spectrally split PVT system: b) fluid-based filter, thin-film based filter.

Therefore, other non-traditional working fluids with improved thermal properties are needed to replace traditional fluids in PVT systems. Nano fluids, introduced by Choi and Estman in 1995[18], represent the best alternative that can be used as a coolant in PVT systems [19].

3- Experimental Design, Construction and Testing Procedure

In this experimental study, a photovoltaic module was designed with copper tubes in a spiral shape behind the solar panel while the second panel was without cooling.

4- Experimental Design, Construction and Testing Procedure

In this experimental study, a photovoltaic module was designed with copper tubes in a spiral shape behind the solar panel while the second panel was without cooling.

4.1 site:

They chose the College of Electrical Technology in the garden adjacent to the laboratory. This is to provide water sources for the experiment as well as for the place of water drainage, as the external water took advantage of the system to irrigate the garden as well as to prevent wastage of water.

4.2 Experimental Design, Setup And Procedure:

Have choose two flat panel displays from the College of Electrical Technology power plants based on their specifications as follows as table 1.

Table 1 Solar panel specifications

Peak Power (Pmax)	60 W
Vmp	18V
Imp	3.33A
Voc	21.V
Isc	3.75A
M S V	1000V
STC: E=1000W/m* AM=1.5 T=25C	

In Figure5, shows the process of bending a copper tube behind a Photovoltaic panel (54cm×86cm), in the form of serpentine, with a diameter of 0.5 mm. The total length of the copper tube required was about 5 meters. We crimped the tube on the Photovoltaic panel, and the distance between the bends was 13 cm. After that, we fixed it with cured silicone and installed three temperature sensors, the first when water enters and the second when it leaves. The third is on the surface of the cooling plate.

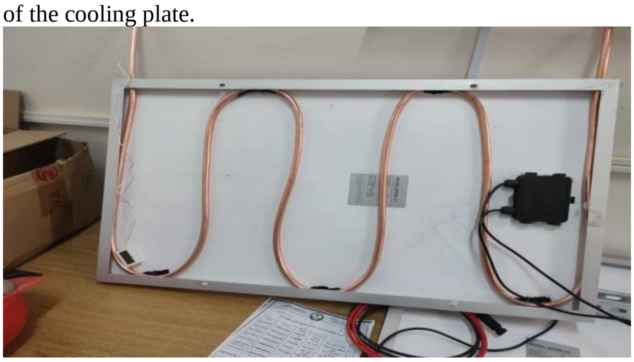


Figure 5 Description of the cooled photovoltaic.

In Figure6, we installed two panels, one with cooling and the other without cooling horizontally calculating the angle allocated to the location.

The experimental system has been tested:

- without water.
- with water.

Figure 6 panels, one with cooling and the other without cooling.

Photovoltaic panels tend to be less efficient due to the negative effect of high temperatures on the performance of photovoltaic cells. As the temperature increases, the output voltage of the solar panel decreases, resulting in a decrease in power generation. For each degree Celsius above 25°C (77°F), the solar panel coefficient typically decreases by 0.3% to 0.5%.

This decrease in efficiency can be significant in areas where temperatures rise significantly during the day, such as deserts. It is best to choose photovoltaic panels with a low temperature coefficient. Using cooling methods, like this experiment, also helps reduce the effects of heat on the efficiency of solar panels.

4.2.1. Cooling With Water

The Property Water. Specific Heat 4.18 J·kg−1·K−1, Density 998.49 kg/m3.

The photovoltaics investigated experimentally using water by passing it through the spiral tubes in Figure 8. The copper tubes in Figure 7 attach the back of the PV system.

Figure 7 The Model PV system.

.4.2.2 Devises and Equipment

Table 2 describes devices used in the experiments that helped us to obtain an effective result.

Table 2 Description of devices.

Devices.	specifically,
Solar Meter	Model-130 1500 W/m^2, sensitivity ±1.5%
Anemometer.	Sensors K-types, RTD and PT100, thermocouple, and Hg thermometer.
Multi meter	Digital multimeter-UT71C/D/E
Gun infrared	infrared thermometer gun infrared thermometer gun

4.3. Serpentine Design

In Figure 5 is Serpentine constructed in the electric laboratory.

4.4. Experimental Design of the cooling unit for the photovoltaic panel.

Before running the experiment:

- •Calibrated all the sensors and transducers before use.
- •considered All Environmental conditions (i.e., being in the environment).
- •The flow rates for the water are constant.
- •Parameters such as temperature for PV (Tpv, Tpvt), Voc, I sc.

4.5. Operating Mode

The control system is given in Figure 8. The normal water flowing from the liquid through the hose to the PV system at the point (Tin). Then the water passes through the point (Tout) to the garden. T panel measured temperature of roof of cooling panel. For no cooling measured by infrared thermometer gun.

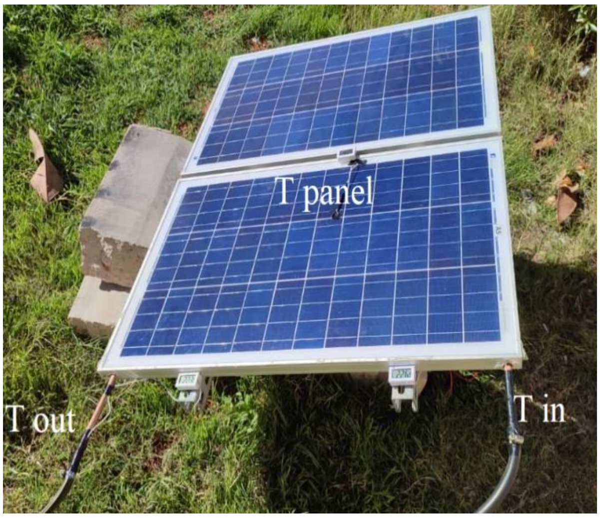


Figure 8 Designed PV

4.6. Analysis Of the Energy System

The equation to calculate the amount of energy is:

$$Q_{u,m} = m_w \times C_{pw} \times \left(T_{o,m} - T_{i,m}\right) \ldots\ldots\ldots\ldots(1)$$

The thermal efficiency of the water of the PV module can be calculated as follows:

$$\eta = Qu\ (Am\ \times It) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

A$_m$ is the area module PV, I(t) solar radiation.

The electrical efficiency calculated as:

$$\eta_C = \eta_0[1 - \beta(T_C - 25)] \qquad (3)$$

Where ῃ0 is the efficiency as, STC, T$_C$ is the solar cell temperature and β is the thermal coefficient. it is almost (0.0045/K).

The solar PV module electrical performance is:

$$\eta_m = \eta_C \times \tau_g \times \alpha_C \times \delta_C \qquad (4)$$

Where τ$_g$ is the transparency, ác is the absorptivity, δ$_c$ as packing factor (0.90, 0.95). Another expression:

$$\eta_m = \frac{P}{A_m \cdot I(t)} \qquad (5)$$

The output power P of the PV from:

$$P = V \times I \qquad (6)$$

Therefore, efficiency “availability” and expressed as follows:

$$\eta_{avail} = \frac{P_m}{PT} \qquad (7)$$

5. DISCUSSION

The photovoltaic panels tested in the first step can be classified as follows:

5.1. Description of results:

5.1.1 Power Cooling and Power without cooling

During the experiment, the difference in electrical power with and without cooling was about 5 watts.as shown in figure 9, we measured the power by solar power millimetre.

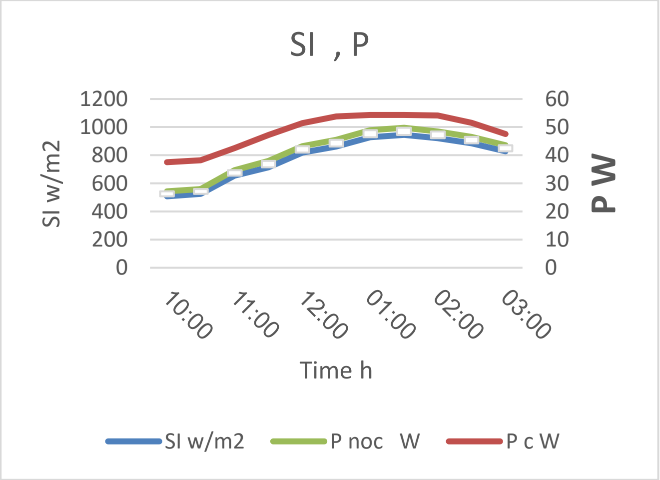


Figure 9. Powe cooling & No cooling

5.1.2 (T in, &T out).

There is a difference between the system entry temperature and the exit temperature, ranging between 5 degrees Celsius. Figure 10

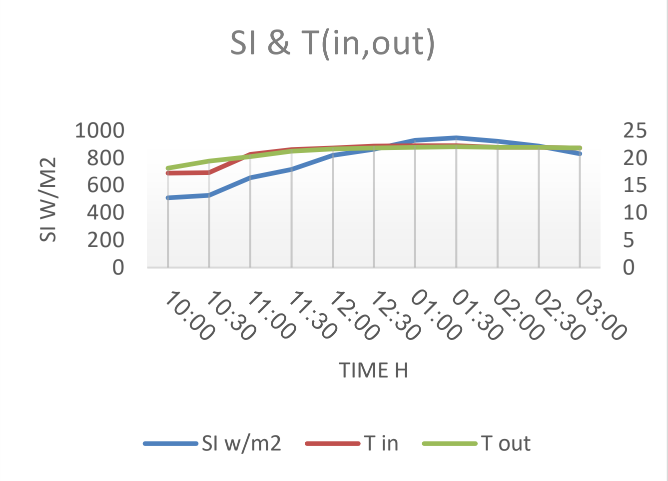


Figure 10. Tin & T out

5.1.3 V & I in the PV cooling:

Voltage and current are affected by the conditions of the solar panel, and when we cooled the photovoltaic panel, both the current and voltage increased in value. As shown in Figure 11

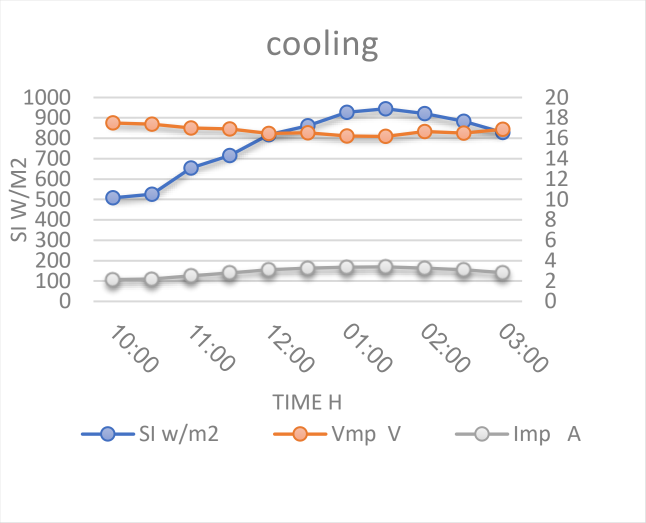


Figure 11. V & I (Cooling)

5.1.4 T pv c & T pv noc

High temperatures affect the performance of photovoltaic power generation. The measurement period was from 10 am to 3 pm. The difference between temperature ranges from 5-7 degrees Celsius, and Figure 12 shows this.

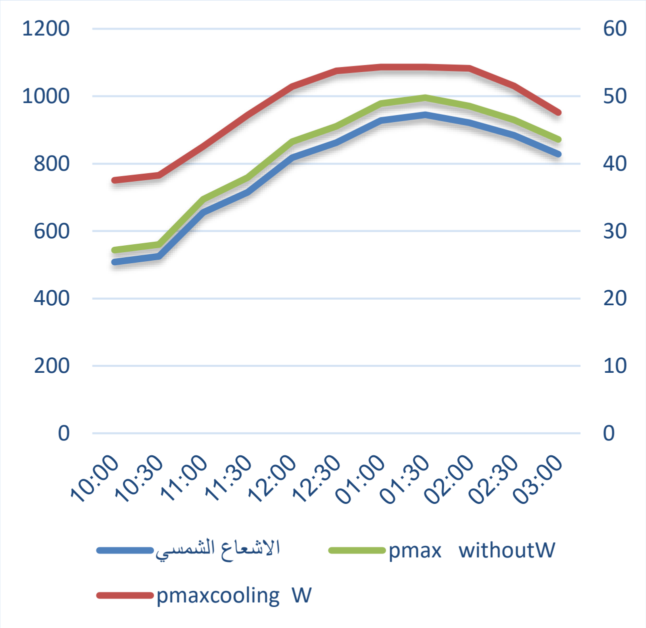


Figure 12 Tpv c & T pv noc

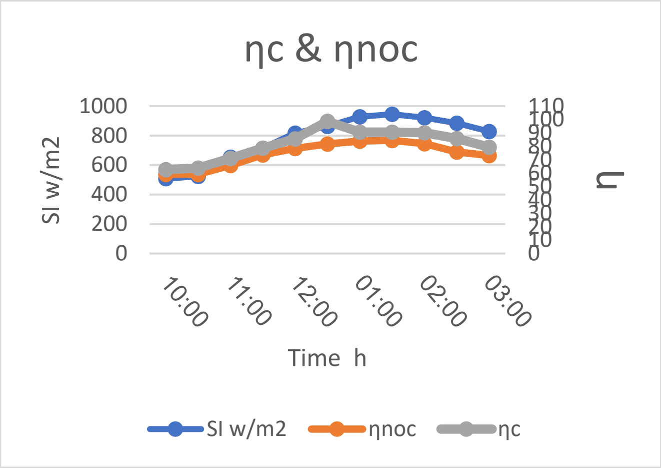
5.1.5. **Efficiency**

The Equation efficiency is

$$\eta = \frac{Power\ output}{power\ input}$$

increased in the cooling from 62.55 to 98.63 % during test period, also the range of no cooling from 59.16 to 84.46. The efficiency is changing between 4-14 % during this period (figure 13).

Figure 13. Efficiency.



6.1. CONCLUSION

Two experimental boards were borrowed from the Department of Electrical Laboratories at the College of Electrical and Electronic Technology. We achieved good results, which were as follows:

- Decrease in PV roof temperature was around 5°C.
- Efficiency of the system 81 %.

6.2. Future Work

Our future work is as follows:

Use a water tank so that the water circulates in a closed loop.

- Other liquids can be used for cooling. as the Nano-fluid.

6.3 Economic cost of the project:

No	Description.	Price
1.	A copper pipe, 0.5 cm in diameter and 5 meters long	150 dinars
2.	3 sensors	75 dinars
3.	Silicone treatment	25 dinars

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