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Assessing The Impact of Transforming Solar Panels from Photovoltaic to Thermal Photovoltaic Systems Within the Iraqi Climate and Studying the Effect of Force Convection

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Abstract. In the quest to reduce dependence on fossil fuels such as oil, coal and gas, and maximize the use of clean and sustainable energy sources, solar energy stands out as a leading and viable option. This form of energy harnesses electrical energy through solar panels. Over the years, photovoltaic panels have advanced significantly, but they face a major challenge: high operating temperatures. Photovoltaic panels use only a portion of the radiant energy they receive, converting the rest into unwanted heat. This not only reduces their productivity, but also shortens their lifespan. To address this problem and enhance the efficiency of incident radiation energy, thermal photovoltaic panels have been developed. This research indicates that thermal photovoltaic panels generate 3 to 4 watts more electrical energy per hour than conventional photovoltaic panels. In addition, thermal photovoltaic panels maintain lower surface temperatures, being 0.2°C to 2°C cooler than standard photovoltaic panels. This improvement extends to temperatures on the other side of the thermal PV panel and at different locations, especially during the summer. Furthermore, the thermal modules inside the PV panels can increase the temperature of the water passing through them by 3 to 4 degrees Celsius, using only one panel. Experiments involving forced convection on thermal PV panels have shown that while forced convection does not enhance electricity production – in fact, its creation consumes more electricity than it generates, reducing net power production by 1.2 to 27 watts – it does improve thermal efficiency.

1. Introduction (use "Heading 1" style)

Worldwide, researchers have prioritized energy development and the exploration of diverse energy sources, with a particular emphasis on clean and limitless alternatives beyond fossil fuels. These alternatives are extensively studied as potential game-changers in the global energy landscape [1].

In the pursuit of harnessing solar energy, manufacturers of solar panels are actively engaged in the development of photovoltaic panels. These panels aim to convert radiant energy from the sun into usable electrical energy for various applications. However, they encounter challenges, and a pivotal concern is the impact of elevated temperatures. During the photovoltaic process, a portion of solar energy is unintentionally converted into heat, leading to overheating of the panels and a subsequent reduction in their electrical conversion efficiency. For instance, crystalline and amorphous silicon cells experience efficiency declines of 0.5% and 0.25% per degree Celsius of temperature increase, respectively [2].

The efficiency of photovoltaic cells diminishes as the operating temperature of the solar cell rises. Therefore, maintaining a low operating temperature is essential for optimal performance [2].

While photovoltaic panels absorb about 90% of incoming radiation, only 15% is converted into electricity. There is substantial untapped potential for heat recovery, approximately 75% of the incoming radiation, within the same solar collector area. Addressing this, the development of cogeneration components like photovoltaic thermal (PVT) collectors becomes crucial. These collectors combine photovoltaic (PV) cells with solar heat absorption components, presenting a more effective solution by efficiently capturing the heat generated within the PV cell [3]. Several researches have been reviewed in this regard [4].

2. The PV Panel

A solar panel, also referred to as a photovoltaic panel, is a device that uses the photovoltaic effect to convert sunlight into electrical energy. It serves as a vital component in solar energy systems, and contributes significantly to clean, renewable energy generation.

Table (2) presents the details and specifications of the solar panel used in this study, which will be subject to many changes to be converted from a PV panel to a PV / T panel to improve the thermal and electrical performance of the panel.

many changes to be converted from a PV panel to a PV / T panel with the introduction of the necessary changes to add the PCM in order to improve the thermal and electrical performance of the panel.

3. The PV/T panel

A PV/T panel, also known as a photovoltaic/thermal panel or hybrid solar panel, is a device that combines both photovoltaic and solar thermal technologies in a single unit. It allows for the simultaneous production of electricity and heat from solar energy, making it a more efficient and versatile system.

In a PV/T panel, the photovoltaic component converts sunlight into electricity, similar to a traditional solar panel. At the same time, the thermal component captures heat from the sunlight and transfers it to a fluid or air, which can be utilized for various heating purposes or even electricity generation through thermal processes.

The PV/T panel offers many advantages over standalone solar PV systems. It increases the use of solar energy by capturing both electrical and thermal energy simultaneously. This integrated design also reduces the total area required for installation, making it suitable for areas with limited space. In addition, the combined system improves overall efficiency by taking advantage of excess heat generated by the photovoltaic cells, which can enhance the performance of the solar cells themselves.

In this study, a cooling system comprising a copper tube is installed behind the photovoltaic panel. The specifications and characteristics of this copper tube are given in Table (1), while Fig.1 shows the shape of the tube at the backside of the solar panel. Water is used as a cooling medium and flows through the copper tube. The addition of this heat transfer system

allows the simultaneous production of both electrical energy from the PV panel and thermal energy from excess heat, thus converting the PV panel into a PV/T panel. Table (1) and Figure (1) provide a comprehensive overview of the copper tube details and the configuration of the solar PV/T solar panel respectively.

Table (1): Characteristics of the cooling tube used in the system

Cooling tube material	Copper
Made of	South Africa
company	Masksal Tubes
Outer diameter	9.53mm
Wall Thickness	0.81mm
Inner diameter	7.91 mm
length	6.85m
ISO 9001: 2015	

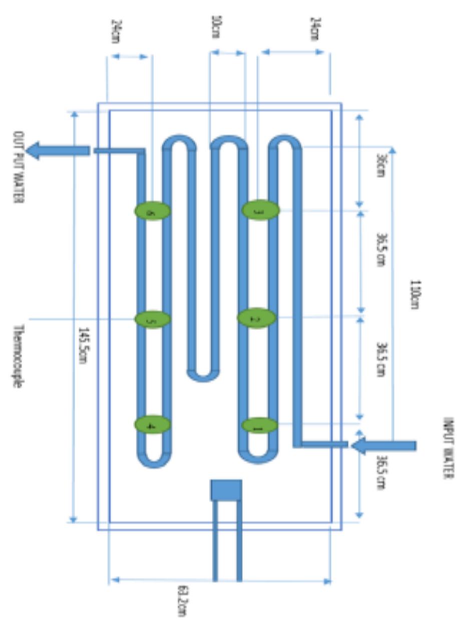

Figure 1: The dimensions of the PV/T panel and the copper tube assembly at the backside of the solar cell with locations of temperature measurement.

Table (2): PV panel details

Manufacturer company	Al-Mansoure State Company / Ministry of industry and minerals
Imp	7.44 A
ISC	8.05 A
Pmp	130.6 W
Voc	22.33 V
Vmp	17.56 V
Vm	1000V
S.N.	101303324
Length of penal	148 cm
Width of penal	66 cm
Module area	0.9768 m2
Quality control	A
Product ID	MCM120
Cell serial	36 (9×4)
Cell area	0.023625 m2
Cell parallel	1
Cell efficiency	15.36%
Module efficiency	13.37%
Slope at ISC	81(Ohm)
Slope at Voc	362(mOhm)
FF	0.727
Current temp. coeff.	10 (micro A/cm2/oC)
Voltage temp.coeff.	-2.1 (mV/cell/oC)
Series resistance	6 (mOhm/cell)
Curve correction fac.	0.05(mOhm/cell/oC)
Image	
Power measure in standard condition (STC)	

4. Research Aims

This study analyzes the influence of photovoltaic panels to thermal photovoltaic panels by studying a variety of aspects, which are discussed subsequently. Two separate circumstances, Case A and Case B, were examined for comparison. In Case A, a typical photovoltaic panel was used according to the specifications listed in Table (1). Meanwhile, Case B used the same panel as Case A, but with the addition of a piping system underneath the panel in direct contact with it, turning it into a photovoltaic thermal panel.

Given that both Cases (A and B) used the same type of photovoltaic panel, the study's results are expected to be practical. Case B is distinguished by its connection to a thermal system, which allows water to circulate beneath the photovoltaic panel. This approach assures that all components are consistent throughout all situations, with the exception of water

flow through pipes in Case B, which is absent in Case A. Furthermore, testing was carried out on successive days to ensure constant environmental conditions. The study also includes the effect of force convection on the thermal performance of photovoltaic panels (power output, surface heat, heat under the panels and thermal energy).

5. Methodology of the Research

When comparing Cases, A and B; Several factors were taken into account, including the back surface temperatures of the panels at six different locations, as shown in Figure 1. In addition, we took into account the electrical power output and front surface temperatures of the panels. Furthermore, we examined the thermal energy extracted from the coolant, water, which flowed in case B at a constant rate of 0.025 L/s. It is worth noting that Case B includes an open water circulation system.

The center of the plate was chosen in terms of dimensions, length and width, as a location to measure the surface temperature of the plate

Fig.2 to Fig.4 show the method of installing the panel in both cases and the measurement tools used in this study, while Fig. 5 displays an integrated diagram of the experiments.

It is important to highlight that the experiments were conducted on consecutive days to ensure uniform environmental conditions around the plate. This approach aims to achieve maximum accuracy. Then, experiments were conducted on the effect of force convection on the operation of thermal photovoltaic panels by studying its effect on the energy produced by the panels and the surface temperature, as well as the thermal energy acquired by the cooling fluid (water). The case that includes force convection with PVT was called Case C Fig.14.

Figure 2. A visual demonstration of the installation of solar panel (Case A) from front view

Figure 3. A visual perspective on the installation of solar panel (Case B) from front view.

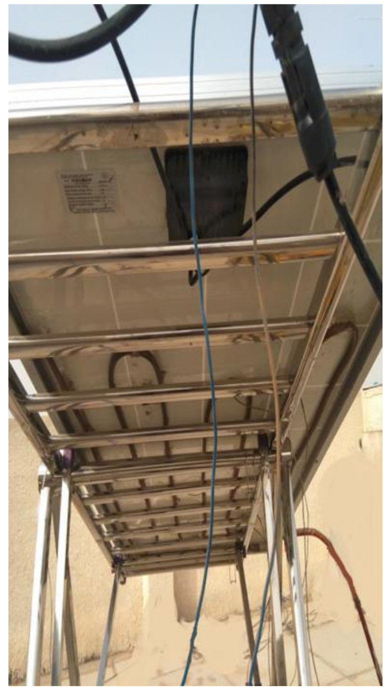

Figure 4. A visual perspective on the installation of solar panel (Case B) from back view.

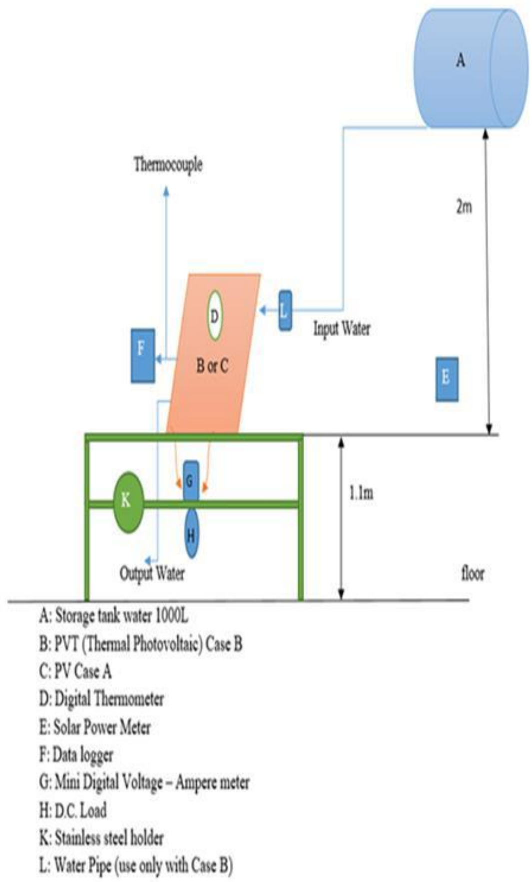

Figure 5. An illustrative diagram of the components of this Research

6. The Difference in the Electrical Energy Produced by the two Panels in Cases A and B

The comparative assessment of Cases A and B involves the scrutiny of power generation spanning a four-day period in September 2023. Notably, September 20 and 22 are scrutinized for Case A, while Case B focuses on September 21 and 23. The outcomes of these measurements are depicted in Fig.6.

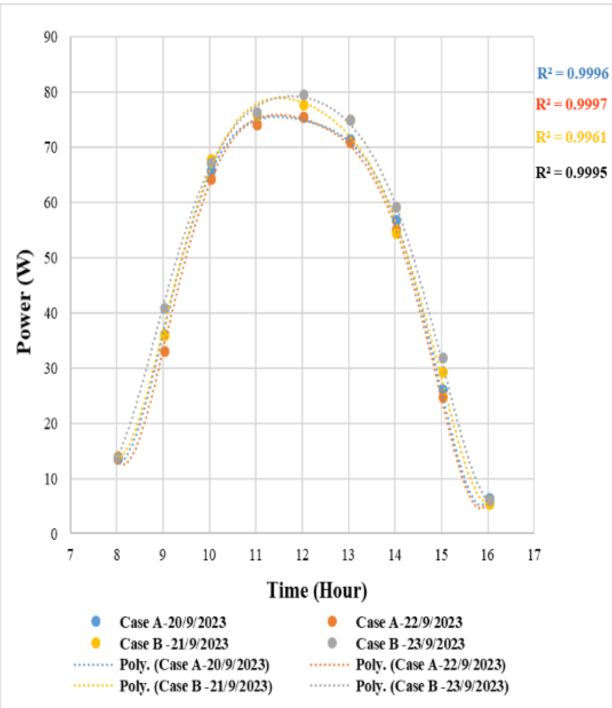

Figure 6. Behavior of the electrical energy for Cases A and B with time in September, 2023, 20 and 22 for Case A, 21 and 23 September for Case B.

7. The Difference in the Surface Temperatures for Cases A and B

One of the parameters investigated and compared in Cases A and B is the surface temperature of the PV unit. The tests were carried out over a four-day period, with two days dedicated to Case A and two days to Case B, all conducted in September, as illustrated in Fig.7. The findings indicate that the surface temperature of the PV module in Case A is higher than that in Case B, particularly during the timeframe from 10 am to 3 pm.

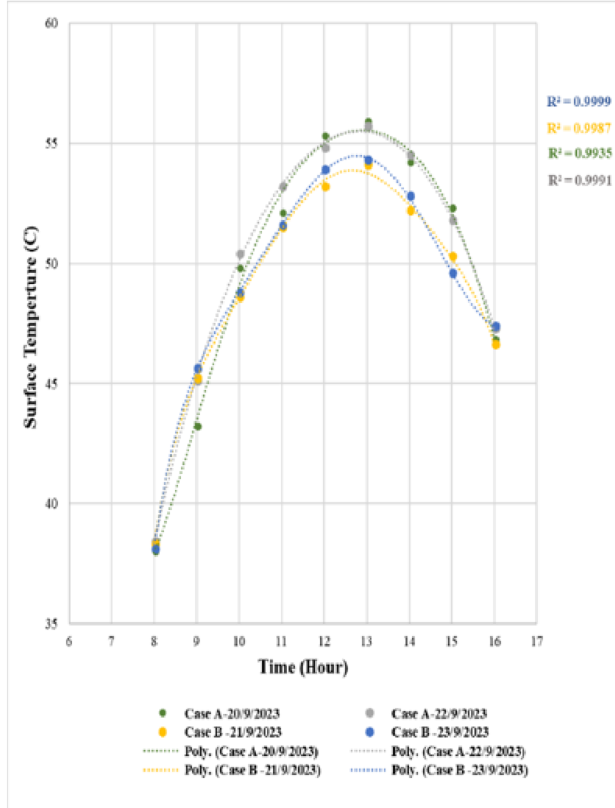

Figure 7. Behavior of surface temperatures Case A and Case B with time in September, 2023, 20 and 22 for Case A, 21 and 23 September for Case B.

8. Behavior of Temperatures Under Solar Panels for Case A and Case B

Fig.1 depicts the arrangement of six thermal sensors (Appendix A-1) positioned on the rear side of each solar panel for the purpose of measuring the temperature on the back surface in both Cases.

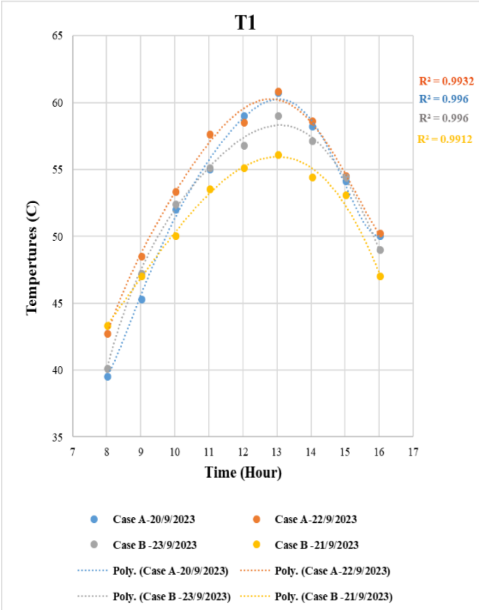

Figure 8. Behavior of temperature (T1) for Cases A and B with time in September, 2023, 20 and 22 for Case A, 21 and 23 for Case B. (The thermal sensor positioned at T1 is depicted in Figure 1.)

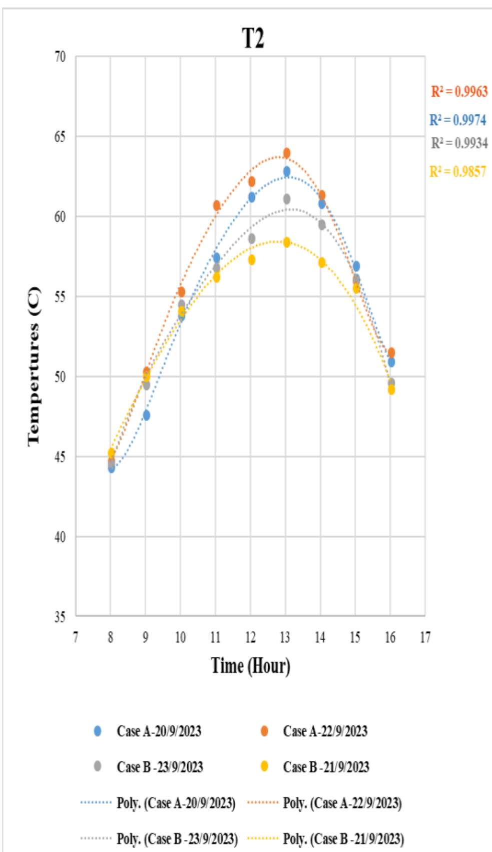

Figure 9. Behavior of temperature (T2) for Cases A and B with time in September, 2023 ,20 and 22 for Case A, 21 and 23 for Case B. (The thermal sensor positioned at T2 is depicted in Figure 1.)

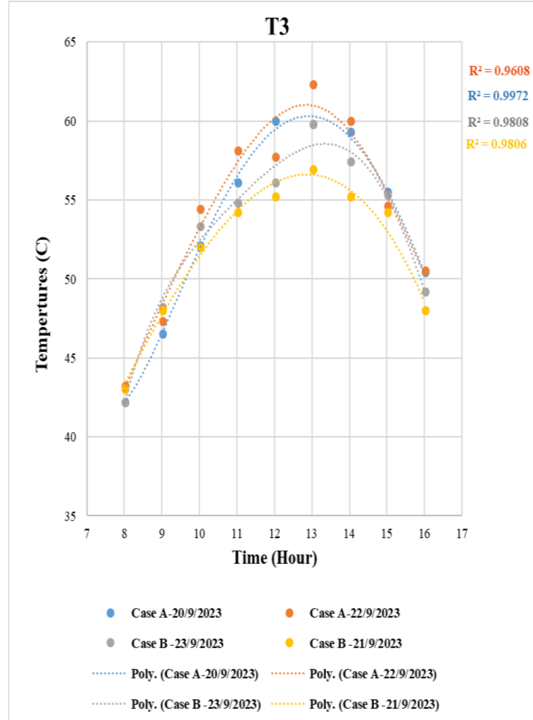

Figure 10. Behavior of temperature (T3) for Cases A and B with time in September, 2023, 20 and 22 for Case A, 21 and 23 for Case B. (The thermal sensor positioned at T3 is depicted in Figure 1.)

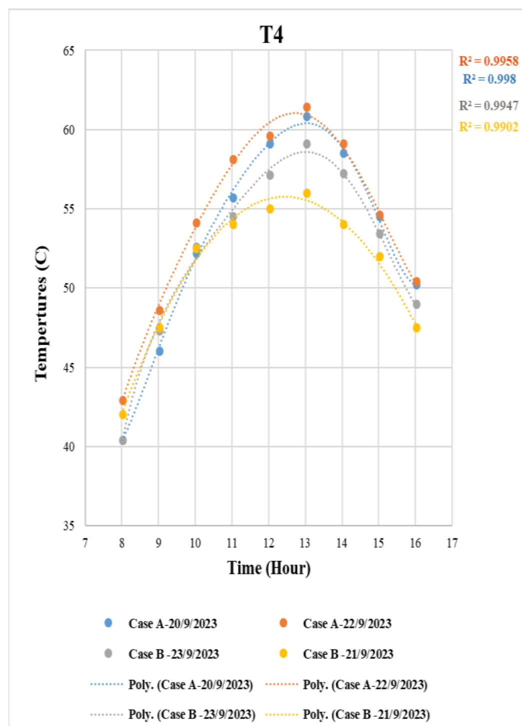

Figure 11. Behavior of temperature (T4) for Cases A and B with time in September, 2023, 20 and 22 for Case A, 21 and 23 for Case B. (The thermal sensor positioned at T4 is depicted in Figure 1.)

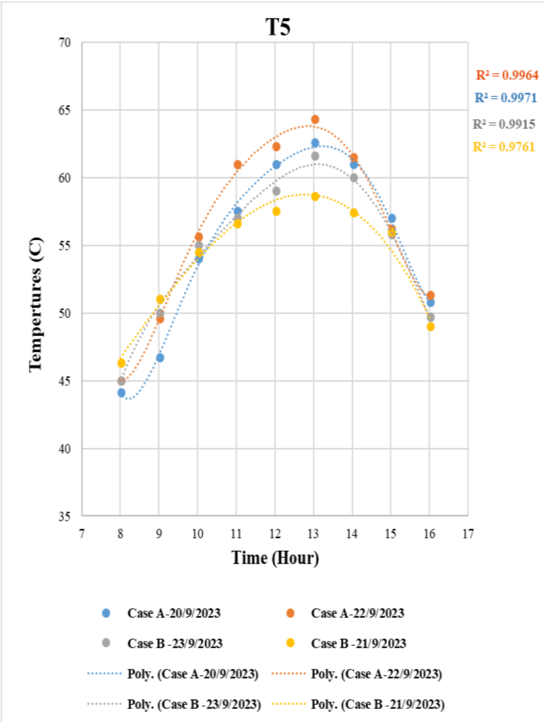

Figure 12. Behavior of temperature (T5) for Cases A and B with time in September, 2023, 20 and 22 for Case A, 21 and 23 for Case B. (The thermal sensor positioned at T5 is depicted in Figure 1.)

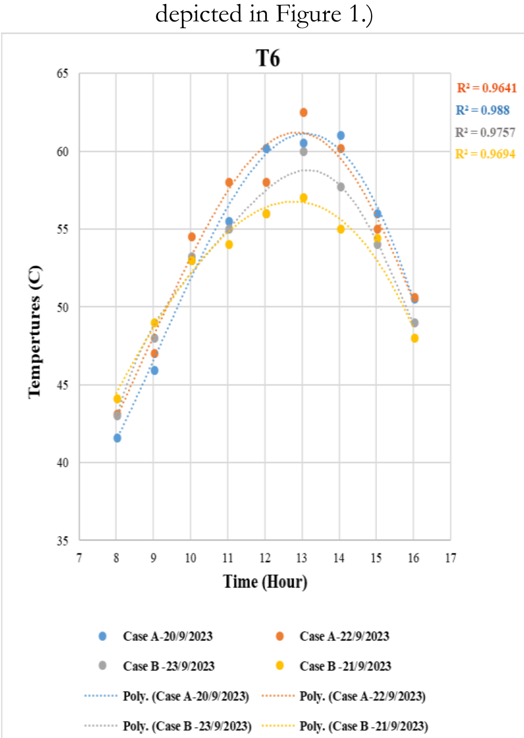

Figure 13. Behavior of temperature (T6) for Cases A and B with time in September, 2023, 20 and 22 for Case A, 21 and 23 for Case B. (The thermal sensor positioned at T6 is depicted in Figure 1.).

9. Effect of Forced Convection

To evaluate the effect of forced convection on the performance of the thermal photovoltaic panels, the panel (PVT) was studied and a comparison was made between two cases, the first without force convection (Case B) and the second case with force convection (Case C), where Case C included the use of the thermal photovoltaic panel as in Case B, with the addition of a fan placed near the upper edge, about 5 cm from the edge of the panel. as shown in the Fig.14 and Fig.15.

Figure 14. A visual demonstration of the installation of solar panel for Case C from front view.

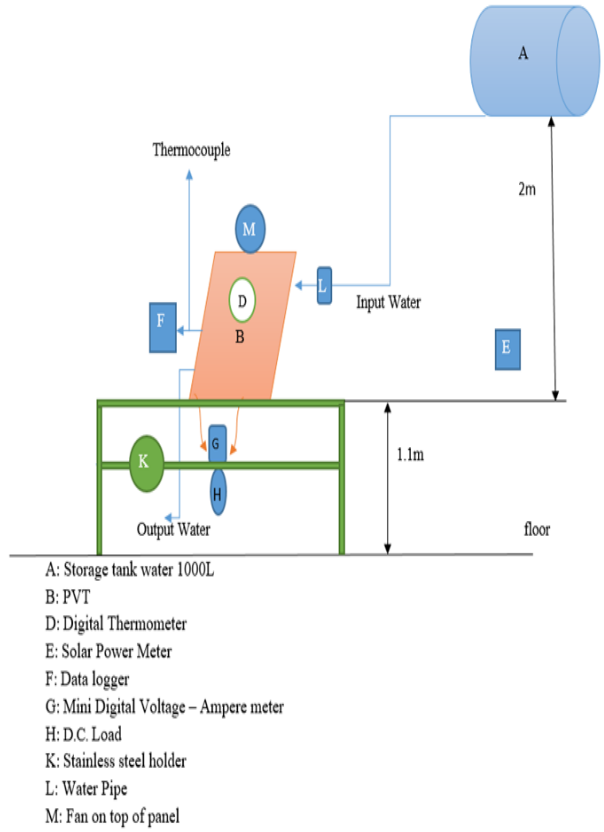

Figure 16. An illustrative diagram of the components of Case C.

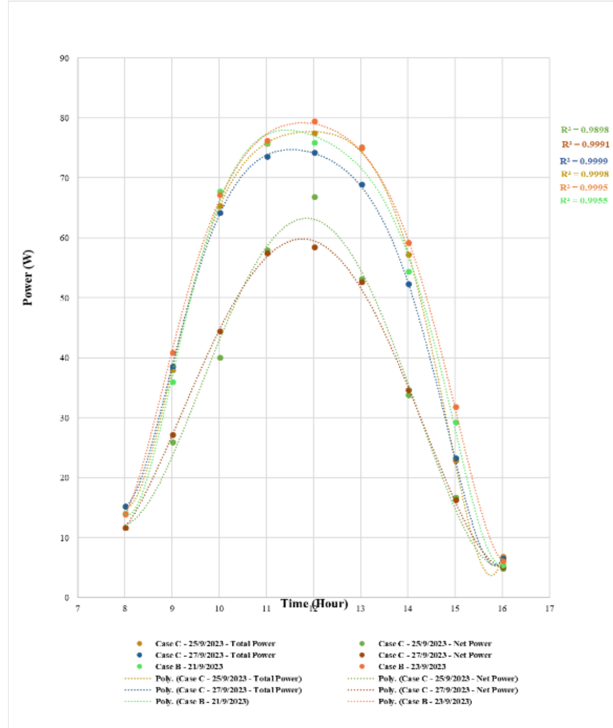

Figure 17. Behaviour of the electrical energy for Case C, and Case B with time in September, 2023, 25th and 27th for Case C, 21st and 23rd for Case B.

10. The Difference in the Electrical Energy Produced by the two Cases B, and C.

In Case C, two measurements were conducted. The first, referred to as Total Power, represents the overall power generated by the panel. To ensure evaluation accuracy, a second reading is obtained by calculating the energy consumed by the fan and subtracting it from the total energy, termed "Net energy."

11. The Difference in the Surface Temperatures for Three Cases B, and C.

An aspect examined and juxtaposed among Cases B, and C is the surface temperature of the PV module. The experiments extended over four days, with two days assigned to each case in September, as depicted in Fig.18. The results showed that there was no positive effect of force convection on the surface temperature of the thermal PV module.

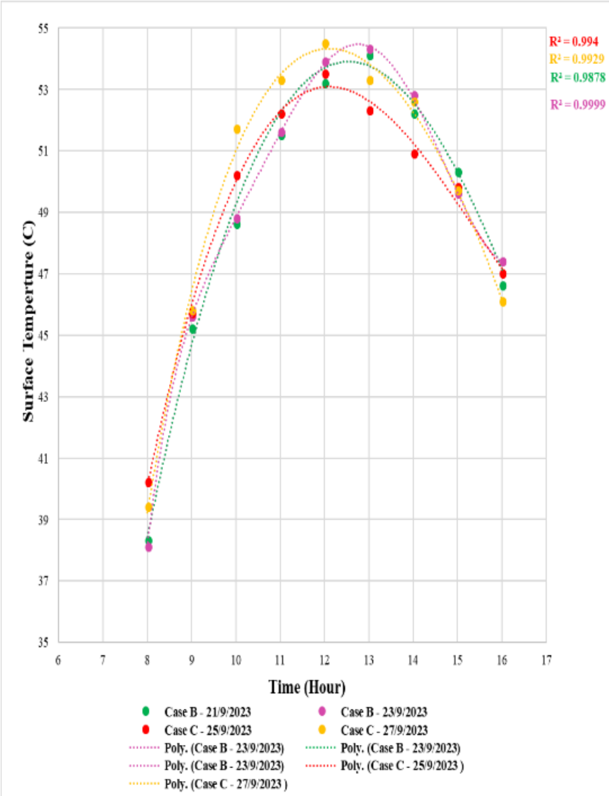

Figure 18. Behaviour of surface temperatures for Case B and Case C with time in September ,2023 ,21st and 23rd for Case B,25th and 27th for Case C.

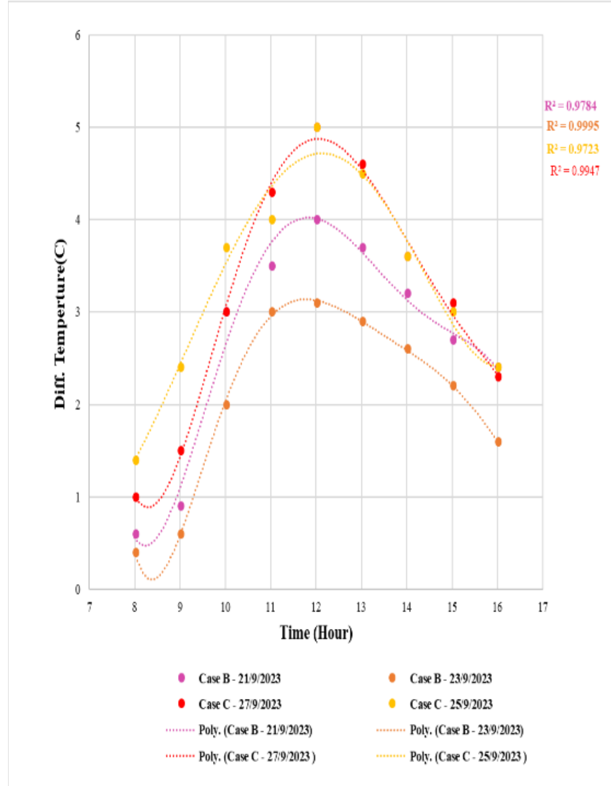

Figure 19. Behaviour of temperature difference between inlet and outlet for Case B, and Case C with time in September ,2023, 21st and 23rd for Case B,25th and 27th for Case C.

12. Difference Between the Inlet and Outlet Water Temperatures for Three Cases B, and C.

a specific analysis was conducted on the temperature difference between the inlet and outlet of the thermal system for Cases B, and C. Fig.19. illustrates that the temperature difference between the entry point of the coolant (water) and the exit point in Case B is smaller when compared to Case C

13. Conclusion

The previous paragraphs highlight the following key points:

1. The electrical energy generated by Case (B) surpasses that in Case (A) by 3 to 4 W/ h.
2. The most notable contrast in energy generation between Panels A and B is evident during the hours spanning from 11 am to 2 pm.
3. 3- In comparison to the surface temperature for conventional solar panels(PV), the thermal photovoltaic panel (PVT) has a lower surface temperature. The surface temperature for the (PVT) decreases from 0.2 oC to 2 oC compared to(PV).
4. The temperature measured under the thermal photovoltaic panel (PVT) record consistently lower values than those recorded under the conventional photovoltaic panel (PV) panel at all the six selected sites where they decreased by (0.2% to 6%) at T1 and T2, (2% to 6%) at

T3 and T4, (0.7% to 6%) at T5, and (0.2% to 5%) at T6.

5. The use of force convection does not improve the electrical energy production of thermal photovoltaic panels (PVT). In fact, creating convection consumes more electrical energy than it adds, which leads to a decrease in energy production. When a fan is placed on top of the thermal photovoltaic panel, the power output decreases from 1.2 to 27 Watts.
6. The use of convection horses has led to an increase in the thermal efficiency of thermal photovoltaic panels.

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