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Analysis of the performance of the PV/ solar chimney: an experimental study

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ABSTRACT

One of the disadvantages of solar PV systems is their low performance due to their high temperature, so the current article aims to study the performance of the PV / solar chimney, so the performance of the solar PV chimney was analyzed and studied during the months (February, March, April) of 2024, as the results showed that the lowest temperature of solar panels was during the month of February, where it reached (65.1ºC) at 12 pm, and that the highest amount of kinetic energy was also during the month of February, where it reached (15.21 MW) at 12 pm, And that the highest amount of electrical energy generated from photovoltaic panels reached during the month of April by (536,966 Watts), and the highest value of the electrical efficiency of photovoltaic panels reached during the month of February, where it reached (14.51%) at the beginning of the Test at nine in the morning, and the highest value of thermal efficiency reached during the month of April, where it reached (63.74%) at 12 pm.

Nomenclature

SC	Solar Chimney
PV	Photovoltaic
PVC	Polyvinyl Chloride
MPPT	Maximum Power Point Tracking
η_{elec}	Electrical efficiency
P_{elec}	Electrical power (W)
I_{solar}	The intensity of solar radiation (W/m^2)
I_{pv}	solar panel- current (A)
v_{pv}	solar panel- voltage (V)
Q_u	Heat gain power (W)
T_a	Ambient temperature (^oC)
C_p	Specific heat (J/kg.K)
h_w	Heat transfer coefficient ($W/m^2.K$)
$T_{o_{air}}$	The temperature at the chimney exit (^oC)
$\dot{m}$	Mass flow rate (kg/s)
A_{ch}	Chimney tower area (m^2).
$V_{ch,exp}$	Velocity of air exiting the solar chimney (m/s)
ρ	Air density (kg/m^3)
P_{kin}	Kinetic power (W)
η_{co}	Efficiency of the collector (%)
α	Absorption
τ	Transmittance
T_{gl}	Glass temperature (^oC)
η_{tot}	Total efficiency (%)

1. Introduction

The energy problem is one of the most problems the world is currently facing due to the large and continuous increase in energy consumption, which is offset by a limited reserve of conventional energy resources, in addition to the environmental problems caused by conventional energy sources, as well as the significant rise in fuel prices, so researchers have developed new and alternative sources, including renewable energies, as there has been a large number of research in this area to benefit from solar energy [1]. Therefore, a reliable, cost-effective and durable renewable energy source should be sought for the energy demand generated in the future, as solar energy is a promising energy source and is freely available to manage long-term issues in the energy crisis among other renewable energy sources [2]. Therefore, scientists and researchers have been searching for new sources that are non - polluting, feasible and low-cost, which led to the emergence of the concept of renewable energy such as solar and wind energy .. etc [3] .The construction of the solar chimney plant to generate electric power has led to convenient opportunities to use non-polluting sources of the environment[4] . Writer Hans Gunther was the first person to propose the idea of a solar chimney system in his book on energy in 1931 to produce electrical energy, and the German engineer Schleich designed it in 1981 for the first time in Spain [5] .The solar chimney is one of the most important systems based on the exploitation of solar energy to produce clean electrical energy, where the maximum value of the electrical energy output of the solar chimney in Manzanares-Spain, which is the first solar chimney constructed in the world, as mentioned earlier, is about (50 kW) [6] . The height of the solar chimney tower (180 m) and the diameter of the tower (5.08 M) and the radius of the solar collector (122 m) and this station continued to operate from (1982-1989) as shown in Figure (1) [7]. The main components of the solar chimney are the solar collector, the chimney Tower, the power generating unit, the turbine and the generator, which is a basic solar energy system that contains a solar collector capable of converting solar energy into thermal energy [8].

Fig .(1) Solar Chimney In Manzanares In Spain[7]

Tayebi et al. [9] conducted a numerical study on the oldest solar chimney in Manzanares - Spain) using the (Fluent) program to analyze the characteristics of heat transfer and air flow in the solar chimney system where the dimensions of the chimney , the radius of the solar collector were 122m) the height of the chimney Tower (180m) and the diameter of the chimney (5.08 m) where the distance between the floor and the cover was (1.7 m) the numerical results showed that the temperature difference between the entry and exit of the solar collector and the air velocity in the collector increases with increasing the intensity of solar radiation and an increase in pressure drop in all parts of the system a comparison was made between the numerical and practical results of the model Spanish where they were compatible . Ahmed et al .[10]conducted an experimental study to study the thermal and electrical performance in (Kirkuk –Iraq) with a longitude line (44.39 E^o) and latitude (35.46N ^{o}) and using photovoltaic panels to generate electrical energy, and the test was conducted on a new design of the solar chimney system, where two models of the solar chimney were designed, in the first model the photovoltaic panels were placed as an absorbing floor of the solar collector with a glass cover and the chimney tower was made of iron and insulated using glass wool, but in the second model it was similar to the first model the only one is to replace the glass cover with photovoltaic panels, as shown in Figure (2), to make greater use of the radiation intensity The results showed that the heat gain in the first model is higher than the heat gain of the second model , but the daily average of the total electrical energy generated by the second model is greater as the total electrical energy of the first model was(75.6W) while in the second model it was (79W).

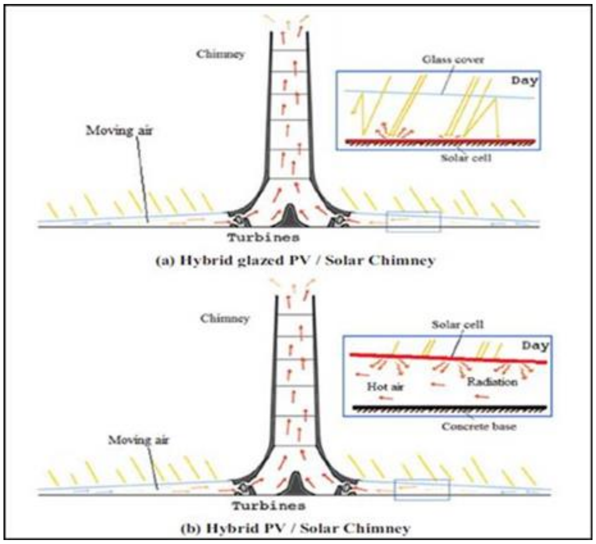


Fig . (2) (a) conventional solar chimney; (b) a hybrid solar chimney with photovoltaic panels.[10].

Afnan et al [11] An experimental study of a hybrid solar chimney system, where it was designed with the following dimensions: [The length of the solar collector is 3.5 m and the width of the solar collector is 3 m, the diameter and length of the chimney Tower is 0.1 m and 3 m], respectively, the study was conducted for three months (December, January and February) and the researcher used six photovoltaic panels placed between the base of the collector and the glass cover, which gives the air free movement up and down the photovoltaic panels, the study was conducted in the city of Kirkuk – Iraq, the experimental results showed that the base of the chimney is the ideal place for the turbine, because the air speed is higher than other sites, and the air speed increases during the day to reach its highest speed at one o'clock in the afternoon , and the maximum kinetic and thermal energy reached W (280, 37) respectively in February , and electrical energy reached 950 W in January at one o'clock in the afternoon. The highest value of electrical efficiency was 17.8% in December.

2. Photovoltaic Theory

2.1 Solar Irradiance

Solar radiation is the most important factor to consider when trying to achieve the desired output power ratio from the PV module. There are two components that make up the irradiance: the initial is the straight ray that travels to the Panel surface, and the second is the reflected irradiance that travels in the opposite direction after being returned from the PV panel surface. It is important to note that the irradiation is not sufficient to provide photovoltaic cells with the energy they need to generate electricity [8]. The direct irradiance that was received by the PV surface can be calculated using Equation 1.

$$I_D = I_{DN} cos\theta \qquad \ldots\ldots..(1)$$

Noted: I_D is represented the straight irradiance, θ is the direct angle, and I_{DN} is direct irradiance.

3. Methodology

One of the disadvantages of solar energy systems is that their efficiency decreases with overheating, as high radiation intensity leads to overheating of photovoltaic panels, which reduces their performance. This research is aimed at analyzing the performance of the hybrid solar chimney and the article is arranged as follows: the practical part is explained in the third section. The mathematical equations are explained in the fourth section, the experimental aspect, analysis and discussion of the results are explained in the fifth section, and the conclusions are explained in the sixth section.

3.1 Experimental Part

Analysis of the performance of the solar chimney over three months (February-March-April), where a photovoltaic / solar chimney was installed on the roof of the renewable energy research unit building at Hawija Technical Institute at an altitude of (8 m) located in northern Iraq on the coordinate line (35.19 Nº, 43.46 Eº) as shown in Figure (3)

- The base of the wooden system.
- The floor of the collector.
- PV panel.
- Glass cover**.**
- Solar chimney Tower**.**

Table (1) Indicate the design dimensions of the solar PV chimney components.

N	Geometric variables	Value
1	Length of solar collector (L_g)	2.42
2	Width of solar collector(W_g)	2.32m
3	Height chimney (H_{ch})	3.00
4	Chimney diameter (D_{ch})	0. 1m
5	Length of photovoltaic solar panel	2.28
6	Width of photovoltaic solar panel	1.13
7	PV panel thickness(hpv)	3.5

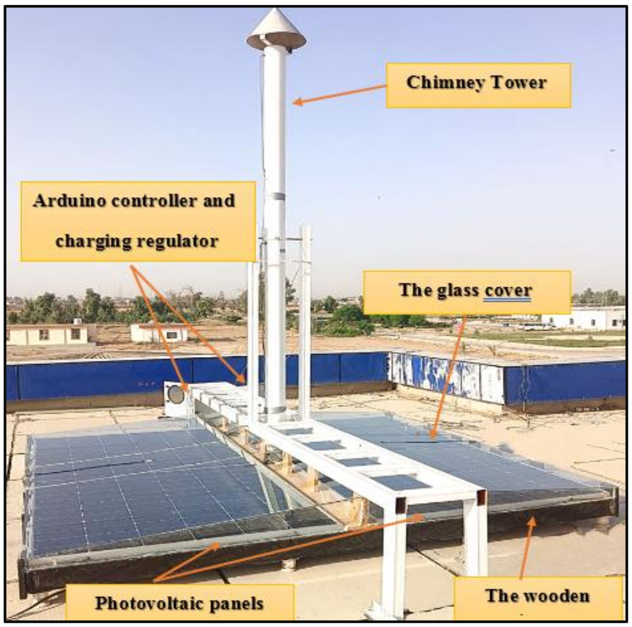


Fig. (3) The solar chimney system used in the study

3.2 System Base

There are several very important factors to take into account for the manufacture of the base of the system, one of the important factors is the weight of the system, as the base must withstand the weight of the system and withstand the wind speed, so the structure was made of wood in a rectangular shape. Its dimensions are [length (2.42 m) ,width (2.32 m), thickness (0.1 m)] and height (0.08 m) from the ground, as the wooden frame is filled with white cork material as it is a heat-insulating, lightweight and low-cost material, the most important of which is available on the market, Figure (4-a) shows the wooden base filled with cork material.

3.3 Floor of the Collector

The floor of the solar collector was made of aluminum material, where it was coated with a layer with a rectangular section of aluminum whose dimensions [length (2.42 m), width (2.32 m), thickness (0.03)] on top of the Cork layer, where aluminum was chosen as an absorbent and lightweight material with high thermal conductivity and low cost .

3.4 Photovoltaic Solar Panels

In this study, two solar panels were used in order to convert solar energy directly into electrical energy, the total capacity of the panels was (1100 W) with dimensions [2.28 m) length, (1.13 m) width, (0.035 m) thickness] and they were installed on the surface of the floor of the solar collector as shown in Figure (4-b), table (2) shows the specifications of the Photovoltaic panels used in the experiment in detail.

3.5 Glass Cover

In the study, a transparent glass cover of the solar collector was used with dimensions [(2.42 m) length, (2.32 m) width, thickness (0.004 m)] where it allows solar radiation to penetrate into the collector and was installed at an angle of inclination (5^o) from the horizon where the height of the glass cover is from the surface of the photovoltaic panels to the Collector outlet (chimney Inlet) (15 cm) and the air inlet distance (0.03 m) above the photovoltaic panels, and silicone was placed on the edges of the glass cover in contact with the chimney in in order to prevent air leakage to and from the solar collector, Figure (4-C) shows the installation of the glass cover, Glass provides high transmittance and low reflection and prevents the penetration of infrared and ultraviolet rays compared to other transparent materials such as plastic.

3.6 Solar Chimney Tower

It is a cylindrical and hollow pipe made of plastic material (PVC) and with dimensions [(3 m) height, (0.1 m) diameter, (0.002 m) thickness], It was installed in the middle of the solar collector where it work as a pressure pipe , where a sealant was placed on the edges of the chimney Tower in contact with the solar collector .

(a) The regular base is filled with a layer of cock

(b) PV solar installed on the base of the system

(c) The glass cover

Fig.(4) The Main Parts of the System

Table (2) Characteristics of the photovoltaic panels used in the study.

Geometric parameter	Value
Model Type	MX -550M MONO CRYSALLINE 10BB PERS SOLAR PANEL
(Maximum power)	550 W
(Maximum power Voltage)	41.60 V
(Maximum power Current)	13.23 A
(Open Circuit Voltage)	49.80 V
(Short Circuit current)	13.99 A
(Dimensions)	(2.28*1.13*0.035) m
(Frame Material)	Aluminum
(Maximum System Voltage)	1500 V DC
(Maximum Seires Fuse)	25 A
(Weight)	29 kg
(Operating temperature in standard conditions)	25 ºC
(Radiation in standard condition)	1000 W

4. Accessories and instruments used in the test:

4. 1 Temperature sensors

Thirteen thermal sensors were used in the experiment to measure the temperatures of the chimney as shown in Figure (5). The thermal sensors were distributed to the chimney parts as shown: one sensor was used in the center of the lower surface of each solar panel, and 3 sensors on the upper surface of each solar panel, one of them in the center of each solar panel, one in the first third of each solar panel, one in the second third of each solar panel . There is one sensor in the center of each side of the glass cover, and three sensors in the chimney Tower, the first at the base of the tower, the second in the middle of the tower, and the third at the top of the tower.

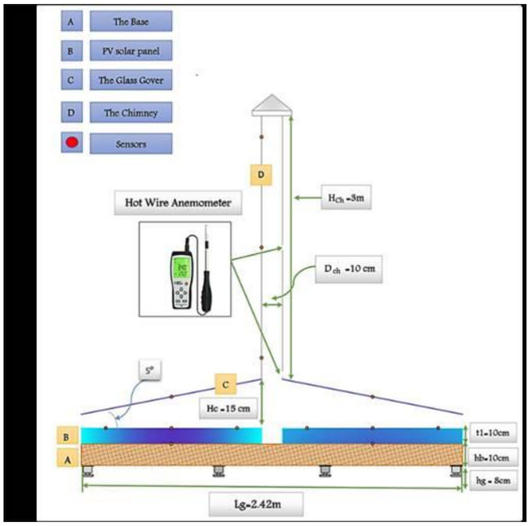


Fig .(5) Distribution scheme of thermal sensors on the solar chimney system

4.2 Digital Anemometer for Hot Wires

The r866a digital hot wire anemometer was used in this test to measure the speed of the air coming out of the solar collector by making two holes, one at the base of the chimney tower and the other in the middle of the chimney Tower in a circular shape with a diameter of (0.02 mm). the holes were covered with a silver insulating tape along the air duct in the chimney, as the distance between the two holes is 1.5 meters, it used to measure the intensity of solar radiation, ambient temperature and wind speed, Davis vintage Pro2 plus weather station .

4.3 lamps (load)

In this test, use six DC lamps with a capacity of one lamp (140 watts), these lamps are connected to the battery and the Arduino controller to control the load and turn off at a certain time so as not to exhaust the battery power, as Figure (6) shows the circuit connection diagram of the designed model. The type of charge regulator (ml2430 / ml2440) regulates the voltage coming from the cells and prepares it before entering the battery, regulates the charging of the battery and the voltage coming out of it for electrical loads, and the charge regulator protects the battery from constant charging (overcharging), as the plates are disconnected from the battery when it is fully charged .Use the battery type Verity, which operates with a voltage (12 volts) and a current (100 amperes), and these batteries were used to store electrical energy generated by solar cells during daylight hours for use in powering Arduino or used when the sun is absent to power number of electrical appliances.

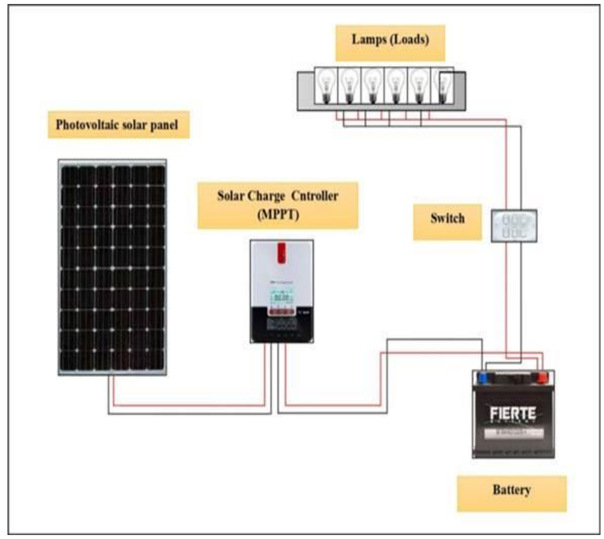


Fig. (6) Circuit connection diagram of the system used in the test

5- Performance Calculation:

To calculate the heat gain of the solar collector through the following equation [2]:

$$Q_u = \dot{m} c_p \left(T_{out} - T_i\right) \quad (2)$$

Where:

Q_u: The useful heat capacity, $\dot{m}$: mass flow rate of air, c_p : Specific density of air, *Tout*: The temperature of the air coming out of the solar collector, *Ti* :The temperature of the air entering the solar collector.

To calculate the mass flow rate the following equation is used[3]:

$$\dot{m} = \rho A_{ch} V_{ch} \quad (3)$$

Where:

ρ : The density of the air coming out of the solar collector, A_{ch} : area of solar chimney, V_{ch}: air velocity. The density can be calculated by the following equation[4] ;

$$\rho = 1.1614 - 0.00353[(T_{out} + 273) - 300] \quad (4)$$

The specific heat can be calculated by the following equation[2]:

$c_p = [1.007 + 0.00004((T_{out} + 273) - 300)] \times 10^3$ (5)

The area of the solar chimney Tower is calculated using the following equation [3];

$A_{ch} = \frac{\pi}{4} {D_h}^2$ (6)

Where:

D_h : Diameter of solar chimney tower.

The solar energy absorbed in the collector can be calculated by the following equation[3] :

$Q_{in=} \ A_{CO} \ I \ \alpha\tau$ (7)

Where :

Q_{in} : Absorbed solar energy, A_{co} : The area of the solar collector, I: The intensity of solar radiation, α : The absorptivity of Photovoltaic panel, τ**:** Glass permeability.

The following relations we obtain the equation used to calculate the efficiency of the solar collector[5]:

$Q_u = \ Q_{in} - Q_{loss} = \ A_{co} I\alpha\tau - h_w A_{co}(T_{gl} - T_{a)}$ (7)

$Q_u = \ A_{co} I\alpha\tau - h_w A_{co}(T_{gl} - T_a)$ (8)

The efficiency equation of the solar collector is obtained:

$\eta_{Co} : \alpha\tau - \ \frac{h_w(T_{gl\_}Ta)}{l}$ (9)

Where:

Tgl: the temperature of the glass cover, Ta : air temperature (ambient), h_w: the coefficient of heat transfer by both radiation and forced load is calculated by the following equation[6] :

$h_w = 5.67 + 3.86V_w$ **(**10)

The electrical power generated by the voltage panels of the system is calculated theoretically by the following equation[7] :

$p_{El \ theo=} \ \eta_{pv} I \ A_{PV}$ (11)

Where: P_{elec} : The electrical power of solar panel, η_{pv} : Electrical efficiency of solar panel, I_{solar}: The intensity of solar radiation, A_{PV} : The solar panel area

The electrical capacity of photovoltaic panels is practically calculated by the equation [7] :

$p_{El \ ex=} i_{pv} v_{pv}$ (12)

Where: v_{pv}:Voltages generated by photovoltaic panels, i_{pv} : current generated by solar panel

Due to the fact that the system is connected to the Arduino controller, the electric power reading is practically taken directly via the Arduino controller screen.

The efficiency of photovoltaic panels is calculated theoretically by the[8] :

$\eta_{pv \ \ theo} = \eta_{ref}[1 - B_{ref}(T_{pv} - T_{ref})]$ (13)

Where: η_{ref} : is the efficiency of voltage panels under standard conditions, the value of which is (0.17), B_{ref} : temperature coefficient at standard conditions, the value of which is (0.04*)* .

The efficiency of photovoltaic panels is calculated in practice by the following equation[9] :

$\eta_{pv \ exp} = \frac{power}{Q_{av}}$ (14)

$\eta_{pv \ exp} = \frac{i_{pv} * v_{pv}}{I * A_{pv}}$ (15)

The kinetic energy of air is calculated theoretically using the following equation[10]:

$p_{kin \ theo} = \frac{1}{2}\rho A_{ch} {V_{ch \ theo}}^3$ (16)

The kinetic energy of air is calculated in practice using the following equation[10]:

$p_{kin \ theo} = \frac{1}{2}\rho A_{ch} {V_{ch \ exp}}^3$ **(**17**)**

Air velocity is calculated theoretically by the following equation[10]:

$V_{ch} = \sqrt{2gH_{ch}\frac{T_{CO,O} - T_a}{T_a}}$ (18)

where: V_{ch} : air velocity at the base of the chimney, g : Ground acceleration, H_{ch} : The height of the solar chimney tower. The air speed when entering the chimney is calculated practically using a Hot Wire Digital Anemometer. The equation used to calculate the overall efficiency of the system is derived by the following relationship[11]:

$$\eta_{total} = \frac{Q_u + p_{pv}}{I * A_{co}} \quad (19)$$

Also, the following relation can be used to calculate the overall efficiency:

$$\eta_{total} = \eta_{CO} + \eta_{PV} \quad (20)$$

5. The Uncertainty Analysis

There is an error rate in the results due to the devices used in the study, where the error rate of the devices used is as shown in Table .3 and the following equation is used to find the error rate of the devices used in the experiment [12]:

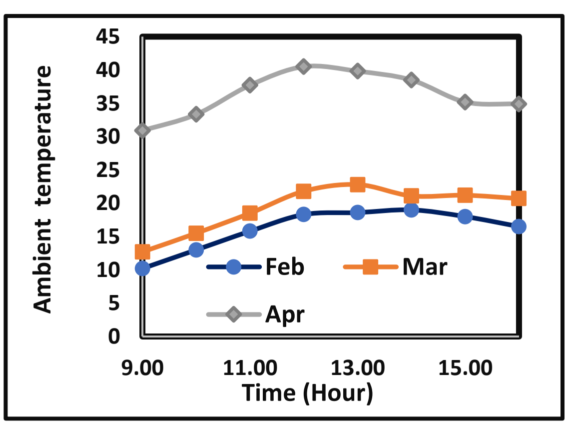
$$\omega_R = \sqrt{\left(\frac{\partial \phi}{\partial x_1} \times \Omega_1\right)^2 + \left(\frac{\partial \phi}{\partial x_2} \times \Omega_2\right)^2 + \cdots \ldots\ldots \left(\frac{\partial \phi}{\partial x_n} \times \Omega_n\right)^2} \quad (21)$$

Table 3: The uncertainty ratio of the devices used in the experiment

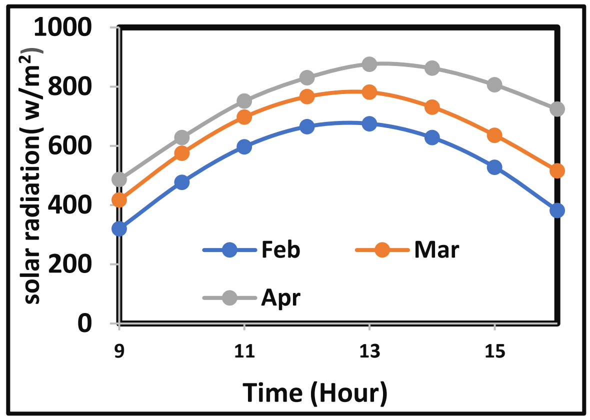
Equipment	Measurement	Error
Hot Wire Digital Anemometer	Air Flow Velocity	±(3%)
Sensor DS18B20	Temperature	±(0.5%)

6. Results and Discussion:

The practical study was conducted for three months (February, March, April) for the year 2024 , where one day was chosen in each month with suitable weather conditions to study the performance and display the results.it shows that the ambient temperature during the three months ranged from (7-30) ºC, and the maximum amount of ambient air temperature reached in the month of April, which is (29.2) ºC at noon, The maximum value of the radiation intensity value in April (876 W / m2) was reached at noon, as shown in figure(7).



(a) The Ambient temperature



(b) Intensity solar radiation

Fig. (7). (a) The Ambient temperature
(b) The Intensity solar radiation

6.1 Change in the amount of temperature of photovoltaic panels over three months

Figure (8) shows the temperature of photovoltaic panels for the month of February ,April and March of 2024 , where it was noted that the temperature of photovoltaic panels in the month of February (24.9) ºC , and in the month of March (35.18)I degrees , and in the month of April (38) ºC at the beginning of the Test at 9 am in the morning , then it increases with increasing intensity of solar radiation , reaching in the month of February (65.1) ºC ,and March (68.62) ºC , and April (69.66) ºC at 12 pm , after that, the intensity of solar radiation begins to decrease, as it reached in the month of February (41.5) ºC, and March (42.98) ºC, and April (45.63) ºC, it becomes clear to us the highest temperatures of panels in April, which makes photovoltaic panels low performance

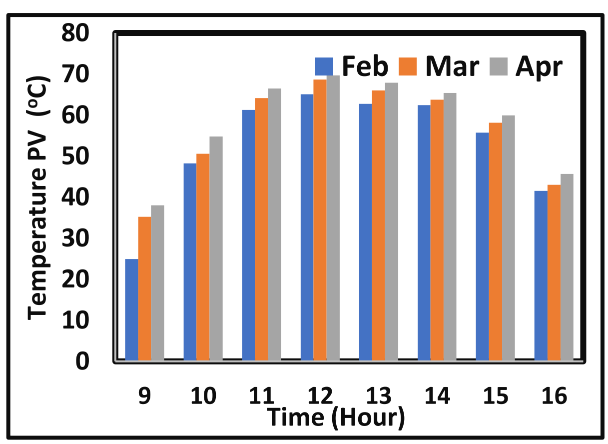


Fig. (8) Temperature of solar panels For the months of February, March and April

6.2 The speed of the air coming out of the solar collector

Figure (9) shows the speed of the air coming out of the solar collector for February ,April and March of 2024, where it was observed that the air speed in February (1.02m/s), in March (0.99 m/s), in April (1.11m/s) at the beginning of the Test at nine in the morning, then the air speed begins to increase to reach the maximum value in February (1.46m/s), in March (1.43m/s), in April (1.45m/s), at 12 pm, after that, the air speed begins to decrease in February (0.97m/s), in March (1.06m/s), and in April (1.04m/s) at 4pm in the evening at the end of the test , We note that the air velocity in February is higher than in March from the beginning of the test until 3pm in the evening, after which the air velocity in February becomes lower than the air velocity in March, because the ambient air temperature in February is low compared to March after 4pm in the afternoon and continues to decrease until sunset, so the air velocity in March after pm in the afternoon is higher than the air velocity in February.

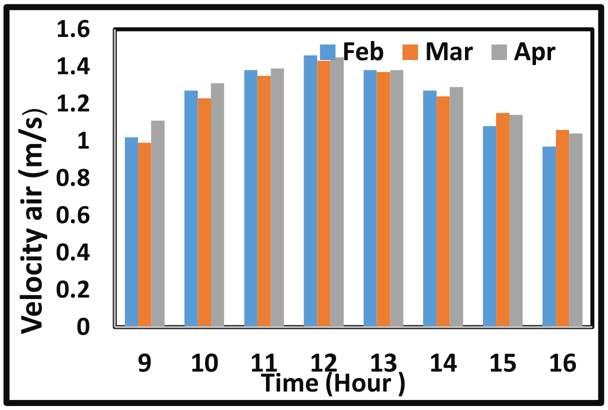


Fig. (9) The Velocity of air leaving the solar collector for the months of February, March and April

6.3 The kinetic power of the solar chimney

Figure (10) shows the kinetic capacity of the solar chimney system for February, April and March of 2024, where it was observed that the kinetic capacity in February (6.525mW), in March (4.661mW), and in April (5.278mW) at the beginning of the Test at nine in the morning, and then the kinetic capacity begins to increase to reach its maximum amount in February (15.21mW), in March (13.304mW), and in April (13.751mW) at 12 pm at noon, after that, the motor ability begins to decrease, reaching in February (3.778mW), in March (5.608mW), and in April (5.163mW) at four pm in the evening at the end of the test .

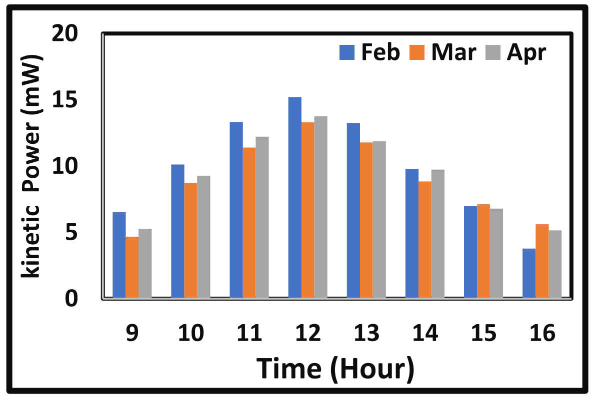


Fig. (10) The kinetic power of the solar chimney for the months of February, March and April

6.4 The electrical power produced by photovoltaic panels

Figure (11) shows the electrical capacity generated by photovoltaic solar panels for the month of February and march and April of 2024, where it was noted that the electrical capacity produced from the panels in February (239.12 W), in March (281.48 W), in April (258.37 W) at the beginning of the Test at nine in the morning, then the electrical power of the photovoltaic panels begins to increase to reach its maximum amount in February (407.76 Watts), and in March (442.92 Watts), and in April (536.96 W) at noon, after that, the electrical capacity of the photovoltaic panels begins to decrease as it reached in February (271.09 W), and in March (334.21 Watt), and in April (505.63 Watts) at four pm in the evening at the end of the test. .

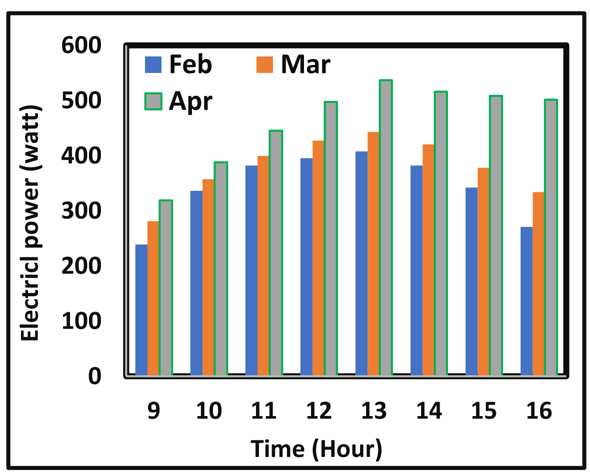


Fig. (11) The electrical energy produced by photovoltaic panels for (February, March, April)

6.5 Electrical efficiency of photovoltaic panel

Figure (12) shows the electrical efficiency of photovoltaic solar panels for the month of February, March and April of 2024, where it was noted that the electrical efficiency of the panels in February (%14.51), in March (%13.10), and in April (%13.93) at the beginning of the Test at 9 am in the morning, then the intensity of solar radiation begins to increases , which leads to a decrease in the efficiency of the panels to reach its lowest amount in February (%11.55), and in March (%10.83), and in April (%11.78) at 12 pm , after that, The intensity of solar radiation begins to decrease, and the efficiency of photovoltaic panels increases, reaching in February (13.78%), in March (12.57%), and in April (13.41%) at 4 pm in the evening at the end of the test.

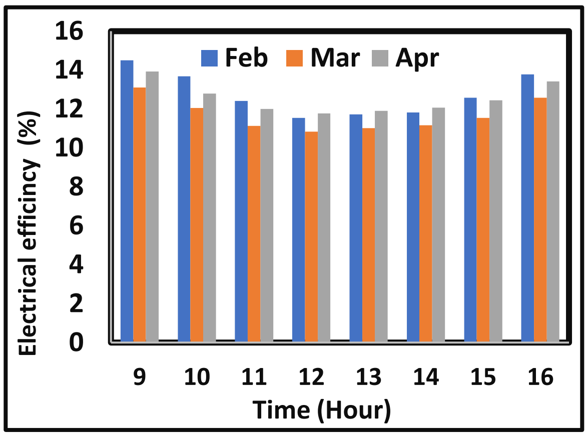


Fig. (12) Electrical efficiency of photovoltaic panels For (February, March, April)

6.6 Thermal efficiency of the solar collector

Figure (13) shows the thermal efficiency of the solar collector and the thermal efficiency depends on the amount of thermal energy absorbed in the solar collector, where the thermal efficiency for February, March and April of 2024, where it was observed that in February (%31.30), in March (%36.06), and in April (%47.50) at the beginning of the Test at nine in the morning, then the intensity of solar radiation begins to increase, so the thermal efficiency of the solar collector increases to reach its maximum amount in February (%48.45), and in March (%51.52), and in April (%63.74) at 12 pm, after that, the intensity of solar radiation begins to decrease, The efficiency of thermal panels decreases reaching in February (27.06%), in March (37.52%), and in

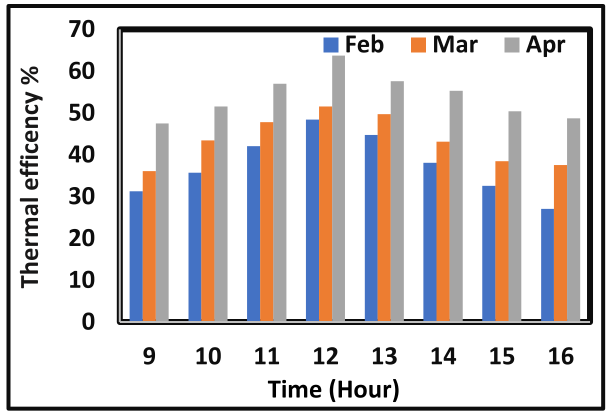


Fig. (13) Thermal efficiency of the solar collector For (February, March , April)

Conclusion

From the results obtained, we conclude the following:

1-The temperature of the solar panels in the month of February is lower than the temperature of the panels in the month of March and April, where the highest temperature for the month of February during the test was (65.1oC), while in March it reached (68.62 oC), and in April (69.66 ºC) at 12 pm.

2-The speed of the air coming out of the solar collector during the test in March is less than the month of February and April at the beginning of the test, where in March it reached (0.99 m/s), while in the month of February and April it reached (1.02 m/s) and (1.11 m/s), respectively, and at midday the air speed for the month of March was also lower than the air speed in the month of February and April, where in March it reached (1.43m/s), while in the month of February and April it reached (1.46 m/s) (1.45 m/s), respectively, while at 4pm in the afternoon at the end of the test the speed in March became the highest, reaching (1.06 m/s), while in February and April it reached (0.97 m/s) and (1.04 m/s), respectively.

3-the highest amount of electrical energy generated by photovoltaic panels is during the month of April, where it reached (536.96 W) at 12 pm, while the highest amount of kinetic energy was during the month of February, where it reached (15.21mW) at 12 pm.

4-the results showed that the highest value of the generated electrical efficiency was during the month of February, where it reached (14.51%) at the start of the Test at 9 am.

5-the highest value of thermal efficiency was during the month of April, where it reached (63.74%) at 12 pm.

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