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Hybrid (PVT) Double – Pass System with a Mixed-Mode Solar For Cooling Small Testing Room

Wisam Hassan Saleh[1] , Abdullateef A. Jadallah[2] ,Ahlam Luaibi Shuraiji[3]

[1, 2, 3] University of Technology / Electromechanical Engineering Department Baghdad – Iraq

Abstract

The demand for clean energy sources increases including solar thermal collectors, which combine photovoltaic systems with thermal collecting system used in the production of electrical energy as well as its use in many applications. As this system is capable of producing converted electrical energy directly from sunlight using the photoelectric effect. In this study, the PV/T solar system was designed and applied to cool a small testing room in the hot weather conditions of Iraq. The designed system was tested in May, June and July. The propose system is used to cool a small testing room using PV/T solar systems. The temperature of the testing room in the month of May decreased by (5-10°C) than the ambient temperature of the Iraqi weather, but in the month of June it decreased by about (6-10°C), in addition to the month of July. The temperature of the testing room was approximately 33°C, and the result showed that increase of the water flow rate as it increased leads to improving the work of the PV/T solar system and thus reducing the temperature of the testing room from(46 to 30 °C) in addition to the intensity of solar radiation whenever it is close to 1000 W / m^2 the designed system works in a manner that good, thus improving its work, and this leads to a good cooling of the testing room. The maximum power is 53.5 °C at 1000 W/m^2 and 0.27 kg/s, so the highest percentage improvement in electrical power is 4.2%. As well as the maximum percentage improvement in electrical efficiency , thermal efficiency and overall efficiency are 3.33% 16% and 7% respectively.

***Keywords**: PVT, Cooling, Mass flow rate, Radiation*

1. Introduction

Electric energy is one of the most important requirements of life in commercial and public services. The Human has begun to benefit from everything around him since he was found on the surface of the earth, as well as solar energy, which has become the focus of attention in human development about clean and renewable energy, since the industrial revolution has increased in demand[1] .There is a great deal of energy in various forms, and fossil fuels have become the first choice for humans, as most of the world's energy (80%) is produced from fossil fuels. The solar energy it is inexhaustible renewable energy, and it is clean energy[2-5].

The solar energy industry is an industry that has contributed to reducing the cost of generating electricity directly from the sun. Currently, the focus is on making the solar panels cost-effective as well as to conserve the environment dedicate renewable energy resources that will adequately support the future without a disgraceful environment while emitting green test chamber gases[6]. The sun is used to provide heat, electricity, light, etc. for domestic and industrial applications by solar technology [7]. Photovoltaics (PV) and renewable energy sources have been developed in recent years [8]. But the beginning developed since 1941. The photovoltaic module is used as the primary sources of electricity in the space and satellite mission. The electricity production expenses from the test room application were reduced staggeringly and the PV module became more economically viable. The new materials were residential and the new technologies accounted for the PV module with an efficiency in many cases of 20%. This type of unit converts the sun's radiation into electricity while providing heat to the system for other purposes. This can be done either with liquid or air coolant. The standard for cooling separate from the heat procedure is unit production cooling which is much more resourceful. The most used liquid is water[3,9]. Many researches applied PVT in many applications such as cooling , heating and draying as Sumit Tiwari et al. 2018[10] presented (PV/T) air collector integrated for green greenhouse dryers. The result show average thermal, electrical, and overall efficiency for the PV/T system was indicated to be 26.68%,11.26%,and56.30%, correspondingly at 0.01kg/s. Mohamed A.Eltawil et.al. 2018[11] presented used PV/T for energy analysis of hybrid solar tunnel dryer. The results stated that the time of drying was changed from 210 to 360 min for the enhanced dryer, while changed from 270 to 420 min for open type dryer. The average efficiency of the PV module and dryer system were 9.38% and30.71%, correspondingly. Meraturefun etal. 2019[12] study the effect of cover design on moisture removal rate of a cabinet type solar dryer for food drying application .The result show that the natural draft was the best type and attic type was worst. It was also observed that the moisture removal content of crops after 1p.m. was higher than before, because of the higher solar radiation. Abdullateef A. Jadallah, 2020 [13] using hybrid(PVT) double-pass system with a mixed-mode solar dryer for drying banana .The result show that the highest reduction was 68% of banana weight at a high mass flow rate of air flow and critical parameter such as temperature distribution of the PVT with dryer room, useful heat gain, The highest heat gain and thermal efficiencies at mass flow rate 0.031 kg/s were 423.7 and 52.98%, correspondingly.

The aim of this paper is design PVT with double pass as for cooling small testing room and show effected mass flow rate of cooling .

2. Mathematical Formulation of PV module

The mathematical description of the current-voltage output characteristics for PV cell can be calculate power and Electrical efficiency [14,15]

The open circuit voltage can be given by:

$$V_{OC} = V_{OCS} + K_V(T_C - T_{ref.}) \quad (1)$$

Where:

V_{OCS}: Open circuit voltage at standard test condition

K_V: Open circuit voltage temperature coefficient

$$P_m = I_{s.c} V_{o.c} \quad (2)$$

$$\eta_{elec.} = \frac{P_m}{P_{in}} \quad (3)$$

Where, P_{in}: Power incident on the PV panel

P_m: Maximum power

η: Power conversion efficiency

A specifications of PV model in Table (1)

Table (1) Specifications of photovoltaic cell

MODEL	SR-100S
Maximum power	84.30W
Open circuit voltage	21.55V
Short circuit current	5.330A
Rated voltage	16.99V
Rated current	4.962A
Short circuit current temperature coefficient	2.10 mA
No. of series cells	32
No. of parallel cells	1

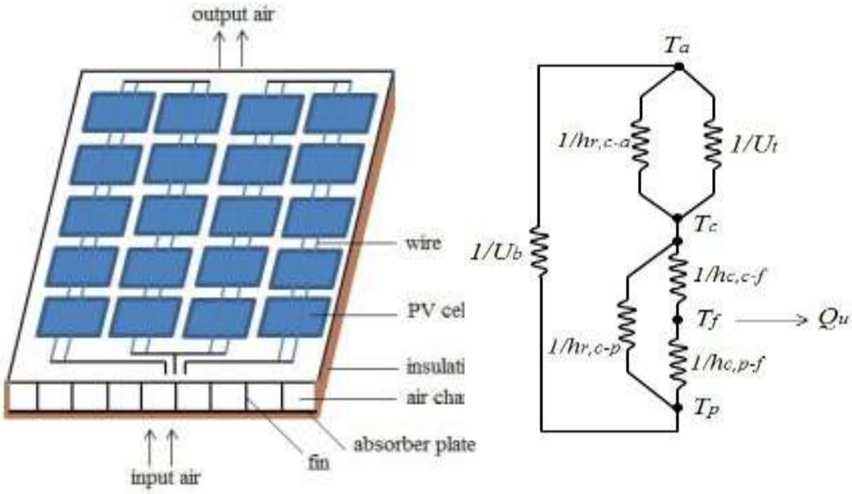
3. Thermal Model of Hybrid PV/T System

The thermal model of the hybrid PV/T system with solar dryer based on the energy balance equations at each part of this system such assolar cell, thermal collector, back plate, airflow in two passages, and dryerchamber.

3.1 Single-pass Air Flow Solar Collector

A schematic of the single-pass air flow of hybrid PV/T system is shown in figure (1). This system comprises of a PV module, double glass cover from top and bottom side of PV module, flat type of solar collector, rectangular fins attached with solar collector, and insulation. Adding fins are improved the thermal performance of PV/T system. The incorporating between the PV module with collector make a passage for flowing air which absorbed the heat from back PV module and solar collector with fins attached and produce a hot output airflow[16] . The convicted and radiated coefficients of single-pass PV/T system with thermal circuit are described in figure (1). The energy balance equations are demonstrated as [17]:

Fig. (1): The equivalent circuit resistance of single-pass PV/T system



a. Solar cells of PV module.

$$\begin{bmatrix} \textit{Solar} \\ \textit{energy} \\ \textit{absorbed} \\ \textit{by PV} \\ \textit{cells} \end{bmatrix} = \begin{bmatrix} \textit{Heat} \\ \textit{loss from} \\ \textit{top of} \\ \textit{PV} \\ \textit{cells} \\ \textit{to ambient} \end{bmatrix} + \begin{bmatrix} \textit{Heat} \\ \textit{convected} \\ \textit{from} \\ \textit{back} \\ \textit{PV} \\ \textit{cell to airflow} \end{bmatrix} + \begin{bmatrix} \textit{Heat radiated} \\ \textit{from PV} \\ \textit{cell} \\ \textit{to ambient} \end{bmatrix} + \begin{bmatrix} \textit{Heat radiated} \\ \textit{between} \\ \textit{PV} \\ \textit{cell to} \\ \textit{thermal} \\ \textit{collector} \end{bmatrix} + \begin{bmatrix} \textit{Electic.power} \\ \textit{rate from} \\ \textit{PV module} \end{bmatrix}$$

$$G_t\alpha_c\tau_g\beta_c = U_{t,c-a}(T_c - T_a) + h_{c,c-f}(T_c - T_f') + h_{r,c-a}(T_c - T_a) + h_{r,c-p}(T_c - T_p) + G_t\beta_c\tau_g\eta_E \quad (4)$$

Where :

U_t = Top losses (W/m^2.K).

α_c = Absorptivity of solar cells.

τ_g = Transitivity of glass cover.

h_r = Heat transfer coefficient by radiation (W/m^2.K).

T_p = Plate temperature ($^\circ$C).

T_a = Ambient temperature ($^\circ$C).

Tf= Mean fluid temperature ($^\circ$C).

$$T_f = \frac{T_{fin} + T_{fout}}{2}$$

Eq. (5) is mathematically arranged to find cell temperature

$$T_c = \frac{G_t\tau_g\beta_c(\alpha_c - \eta_E) + (U_t + h_{r,c-a})T_a + h_{r,c-p}T_p + 0.5h_{c,c-f}(T_{f,in} - T_{f,out})}{U_t + h_{r,c-p} + h_{c,c-f} + h_{r,c-a}} \quad \ldots\ldots (5)$$

Where :

β_c : Packing factor.

b. Fluid flow

$$\begin{bmatrix} Useful\ heat \\ rate \\ from\ upper \\ passage \end{bmatrix} = \begin{bmatrix} Heat\ convected \\ from\ PV\ cells \\ to\ airflow1 \end{bmatrix} + \begin{bmatrix} Heat\ convected \\ from\ thermal \\ collector\ to\ airflow1 \end{bmatrix}$$

$$Q_u = \varepsilon h_{c,p-f} \left(T_p - T_f'\right) + h_{c,c-f} \left(T_c - T_f'\right) \quad (6)$$

Where:

Q_u = Useful heat gain (W).

ε: Effectiveness of fin.

T_f' : Average fluid temperature

4. **Experimental Set up**

The implementation the PV panel enhancement techniques using cooling system. It is written in many section concerned with experimental apparatus measurement and procedure of test. The experimental test rig was installed in University of Technology\ Electro mechanical Engineering Department, Baghdad, Iraq .The installed conditions of PV panel were (with **33°** tilt angle to the south) which are suitable to Baghdad condition (33.3º latitude, 44.4º longitude)for receiving higher heat flux .Many tests of experimental rig were conducted locally to study many parameters of the PV cooling system. The experimental work of the proposed PV/T as solar cooling system which is shown in figure (2) and (3). In this work, glass to glass hybrid PV/T air-based system with solar cooling chamber is conducted experimentally for different mass rates of the airflow, one case of double pass airflow passage, two types of thermal collectors. Further, the design and manufacture of this system which necessary to construct; are illustrated in detail. The cost of the PV cells rapidly descending and the construction of the thermal collector is the cheapest as itis constructed from aluminum. Further, the accessories are widely available with fair prices.

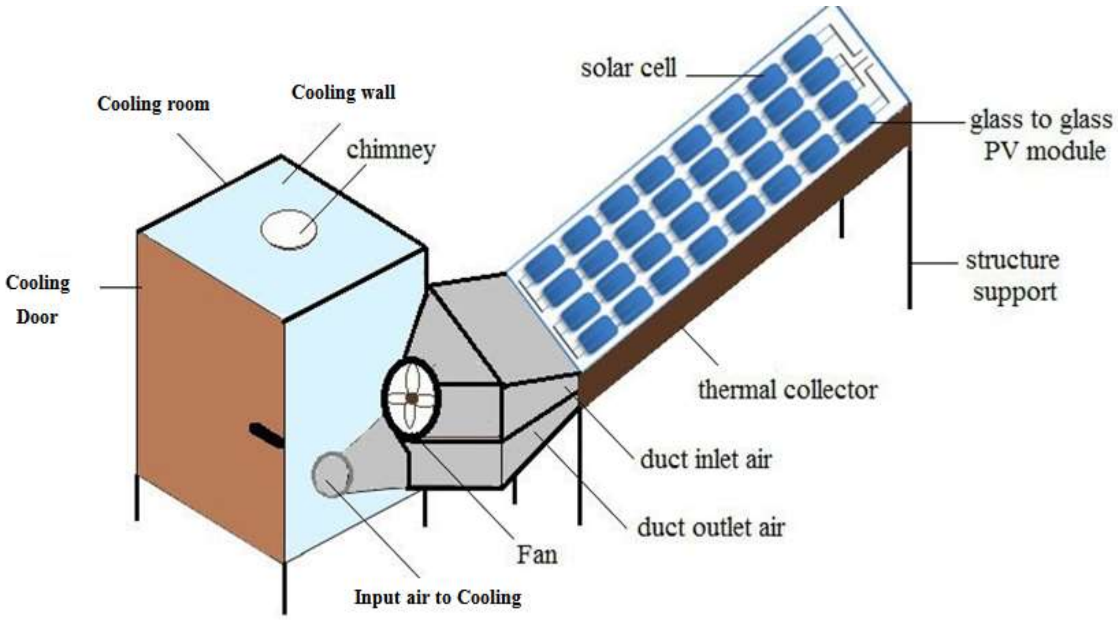


Fig. (2): Schematic Diagram of proposed PV/T system

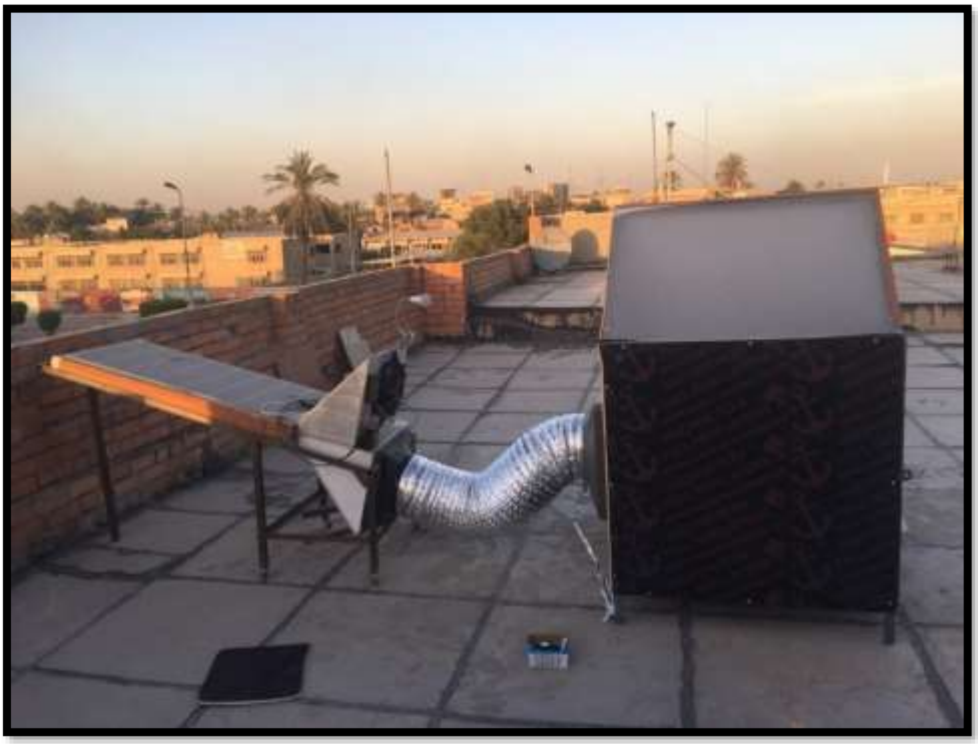


Fig. (3): Photograph of proposed PV/T system

5. Discussion

Figures (4,5,6) shows a comparsion temperature of testing room when cooilng by PV system in summer senon of Iraq weather in (May,June,July) months with temperature of ambient. From these curves, the temperature of the testing room and cooling system of 10 °C can be observed in May, June, and July, respectively. Figure(7) show an effect of mass flow rate of temperature of testing room in May,June, and July month.This curve show when increas a mass flow rate this cause reduce in temperature of testing room. Figure(8) show an effect of radiation of temperature of testing room.This curve show when increas a radiation this cause reduce in temperature of testing room. Because an increase in the flow rate leads to an increase in heat transfer inside the room. Figure (9) shows the power change during daylight hours at different air flow rates, and it becomes clear that with the increase in radiation, the electrical power increases dramatically, as more electrons are separated from the solar cells and the electric current, and can be noted that the maximum power is 53.5 °C at 1000 W/m^2 and 0.27 kg/s, so the highest percentage improvement in electrical power is 4.2%. Maximum power gained is 51.95 W at 13:00 PM. Figure (10) shows the variation in electrical efficiency during the day, as the cell temperature changes during daylight hours and thus affects the decline in electrical performance. Can be noted that the increase in electrical efficiency is affected by the increase in the air flow rate by extracting heat from the photovoltaic cells and reducing the cell temperature. For this reason, the maximum electrical efficiency is 12.2% at 9:00 am, 0.27 kg/s, also the maximum percentage improvement in electrical efficiency is 3.33%. Figure (11) shows the heat gain during daylight hours as it increases if the air flow increases. The maximum value of useful heat gain reached 286.5 W at 0.27 kg/s at 13:00 pm. Figure (12) shows the improvement in thermal efficiency during daylight hours from 9 am to 13:00 pm, as can be notice its increase with the increase in high solar radiation. Where the maximum thermal efficiency was 38% at 13:00 pm and at the highest mass flow of 0.27 kg/s. Figure (13) shows the increase in overall efficiency. Where can be note that the maximum overall efficiency is 77% at 9 pm, and at 0.27 kg /s is high due to the electrical efficiency at 9 am.

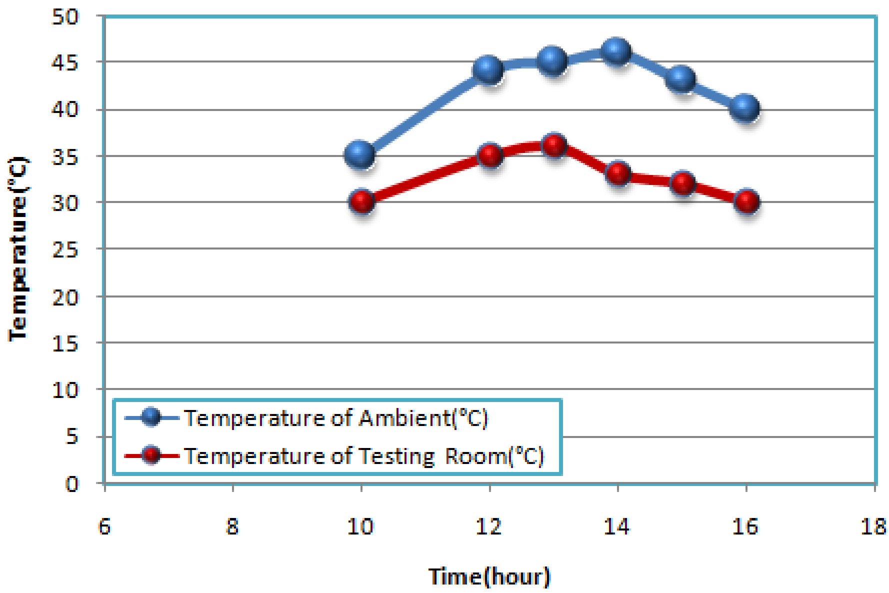


Fig.(4) Temperature with time of testing room in May

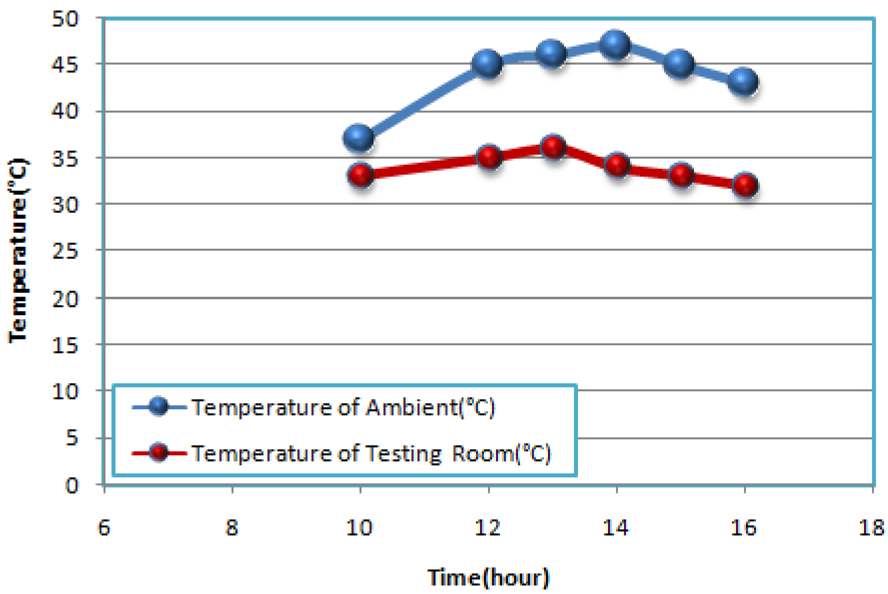


Fig.(5) Temperature with time of testing room in June

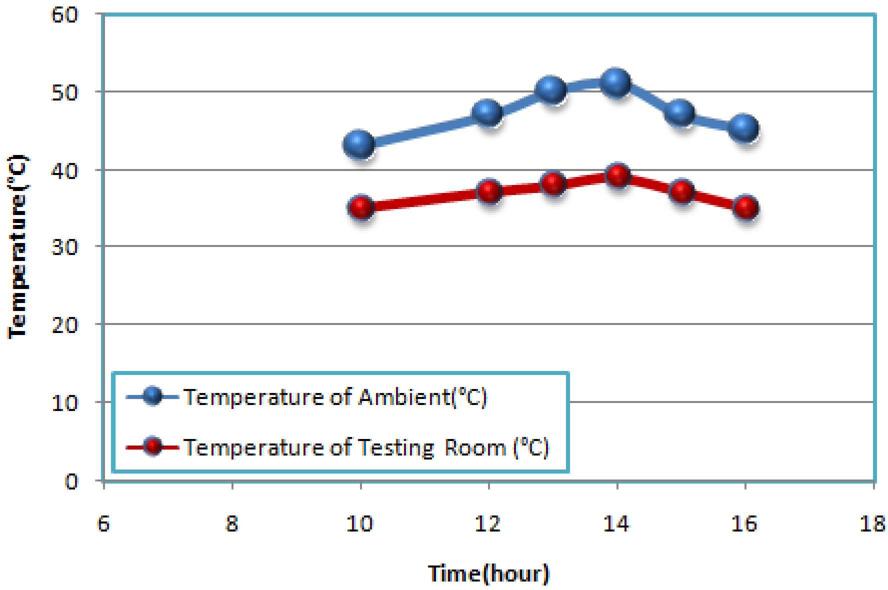


Fig.(6) Temperature with time of testing room in July

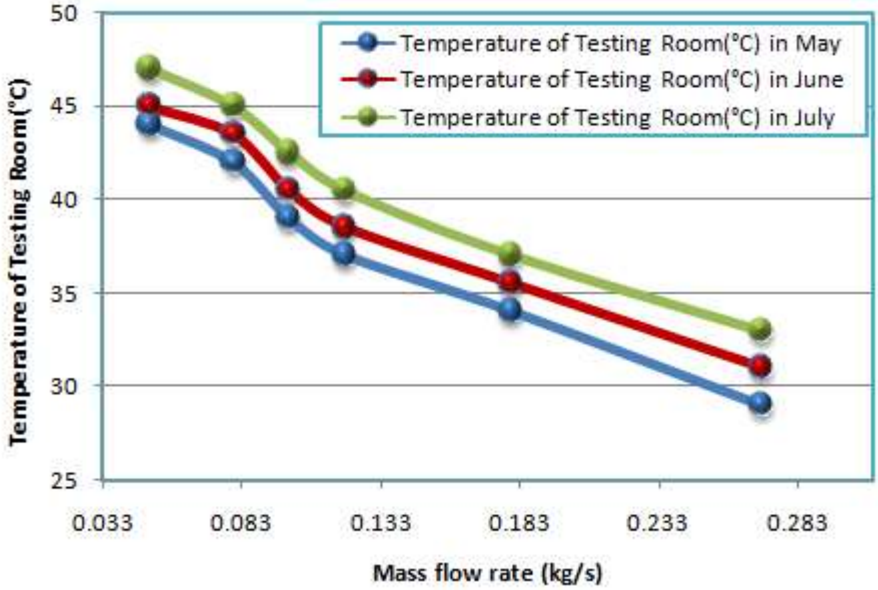


Fig.(7) Temperature of testing room with mass flow rate in May,June, and July month.

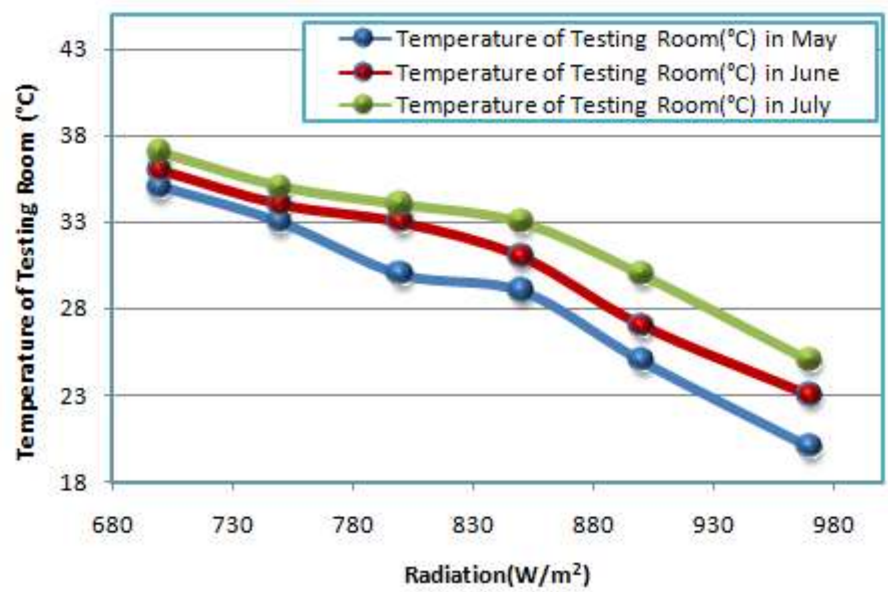


Fig.(8) Temperature of testing room with Radiation in May,June, and July month.

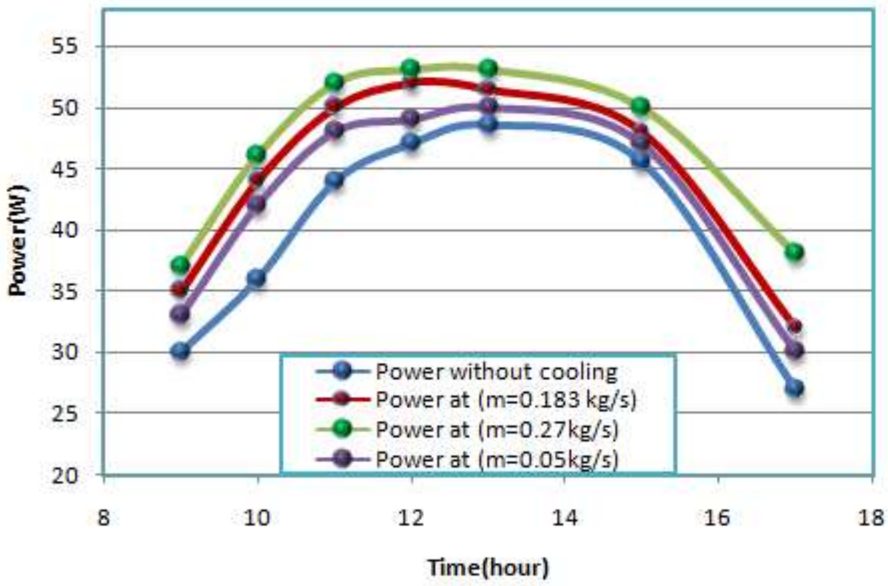


Fig.(9): Power with time at various of mass flow rates for double-pass PV/T system.

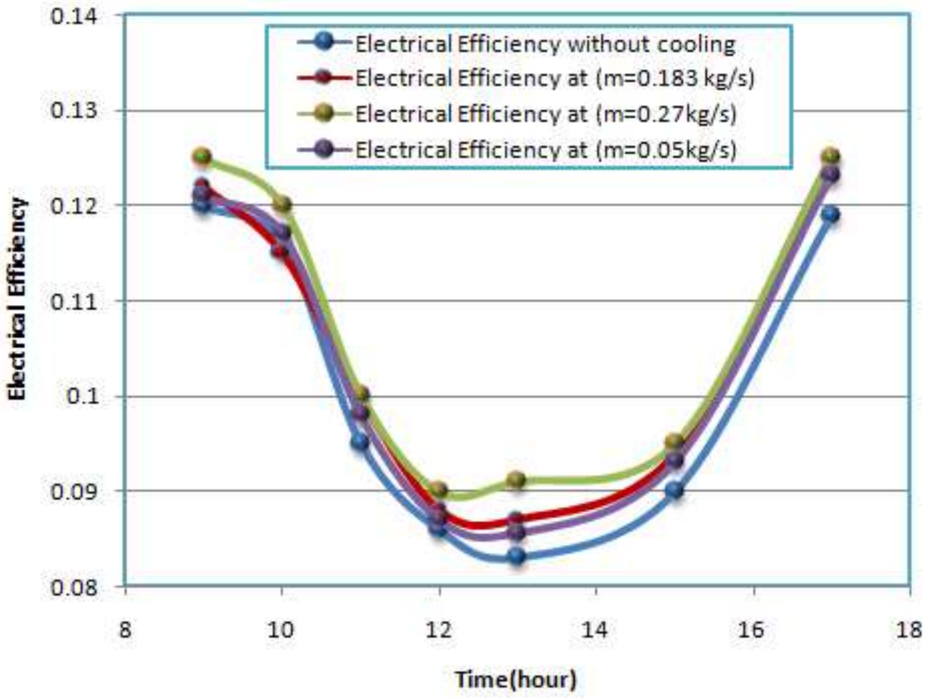


Fig.(10): Electrical efficiency at various mass flow rates for double-pass PV/T system.

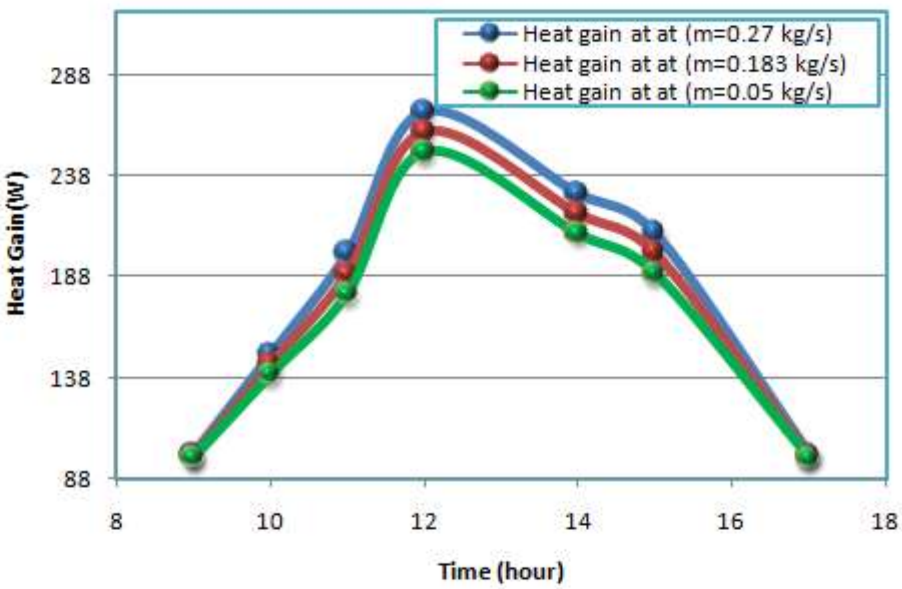


Fig.(11): Heat gain with time at different values of mass flow rates of air for double-pass PV/T system.

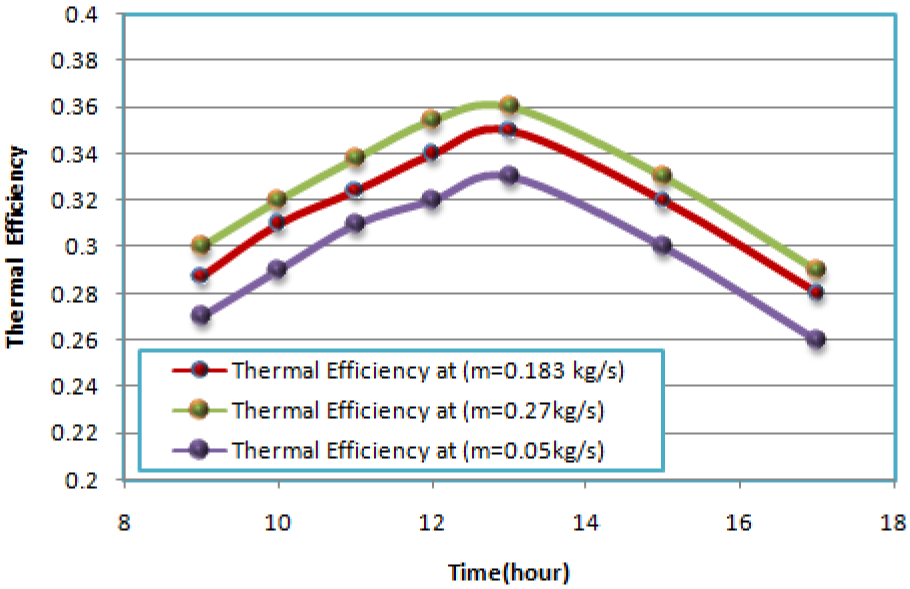


Fig.(12): Thermal efficiency with time at different values of mass flow rates for double-pass PV/T system.

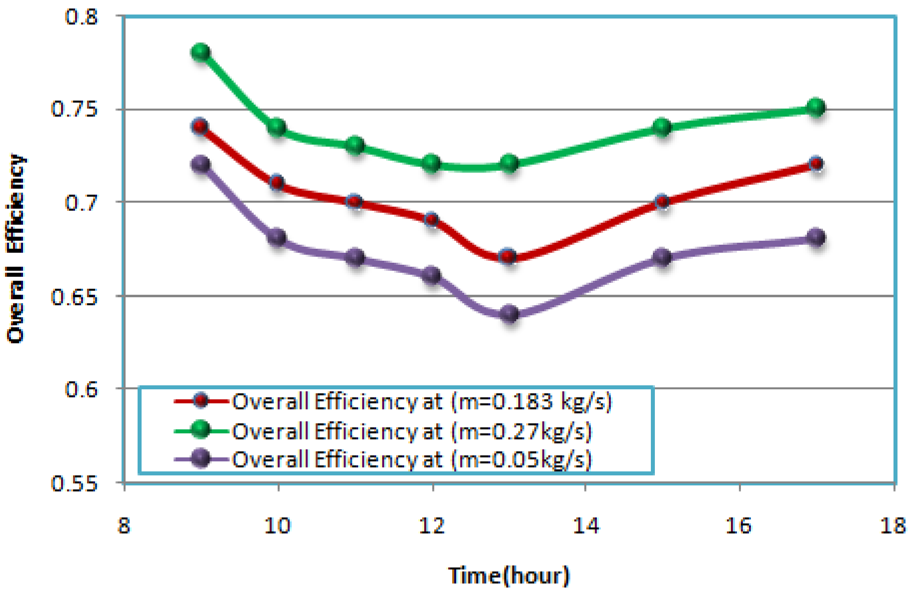


Fig.(13): Overall efficiency at different values of mass flow rates for double-pass PV/T system.

6. Conclusion

In this work designed to cool a small Testing Room using PV/T solar systems, can be concluded from this study , the temperature of the Testing Room in the month of May decreased by (5-10°C) than the ambient temperature of the Iraqi weather, but in the month of June it decreased by about (6-10°C), in addition to the month of July, The temperature of the testing room was approximately 33°C, and that study showed that the water flow rate as it increased leads to improving the work of the PV/T solar system and thus reducing the temperature of the testing room from(46 to 30 °C) in addition to the intensity of solar radiation whenever it is close to 1000 W / m^2 the designed system works in a manner that good, thus improving its work, and this leads to a good cooling of the testing room by percentage improvement as 22 %. The maximum power is 53.5 °C at 1000 W/m^2 and 0.27 kg/s, so the highest percentage improvement in electrical power is 4.2%. As well as the maximum percentage improvement in electrical efficiency , thermal efficiency and overall efficiency are 3.33% 16%and 7% respectively .

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