International Journal of Engineering, Science and Mathematics
Vol. 7 Issue 10, October 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

PERFORMANCE OF SOLAR PHOTOVOLTAIC THERMAL AIR (PVTA) SYSTEM WITH DOWNSTREAM WAVY FINS

J. Charles Franklin,

Lecturer (SG), Seshasayee Institute of Technology, Trichy - 10

ABSTRACT

A new photovoltaic thermal air (PVTa) system with fins in the downstream portion of the air channel was tested for its thermal and electrical performance in this work. For this purpose, two fin configurations were opted. One is a longitudinal fin oriented longitudinally along the air channel and the other is a wavy fin placed in the direction of air flow. The experiments were conducted between June and September months of the year 2018 on daily basis in the location of Tiruchirappalli, a city in Tamilnadu state of India (10.82 latitude and 78.70 longitude). The results indicated that PVTa system with downstream wavy fins performed thermally better than the PVTa system with out fins.

Key words: Solar PVT, panel temperature, air channel, fin, downstream.

Introduction

Harvesting solar energy to meet the heat load and electricity generation reduces the emission of greenhouse gases and carbon foot print. Dependency upon the rapidly depleting petroleum resources to produce electricity is being replaced presently by solar photovoltaic (PV) technology. Due to unavoidable higher operating temperature than the ambient, PV systems have low solar to electrical energy transformation efficiency and prone to physical structural worn outs. These drawbacks are often eliminated by restoring to a thermal control method so as to reduce the operating temperature of the PV. Instead of adopting a thermal control method solely for the purpose of heat removal from PV panel surface, it is profitable in terms of energy cost to apply the heat removed from them for a variety of household and industrial needs.

Literature Review

This energy conservation measure led to the evolution of photovoltaic thermal (PVT) hybrid system [1]. The unwanted heat from PV panel is usually recovered from their rear side by maintaining air flow or water flow, and could be used for heating air or water respectively. Based on the heat extraction medium like air and water, PVT technology can be broadly grouped as PVT air (PVTa) technology and PVT water (PVTw) technology. Recent PVT systems [2, 3] incorporate novel heat extraction techniques with high thermal conductivity nano fluids, latent heat of fusion with the use of phase change materials (PCM), latent heat of evaporation in heat pipes and semiconductor based thermo-electric modules. Of the various PVT system designs, PVTa system is much simpler due to lesser constructional complexity, operational and maintenance overheads. But, it is found that the major hurdle with PVTa system is the low values of mass density and specific heat of the heat extraction medium (i.e., air) which affects the heat extraction rate from the heated PV rear surface [4]. Therefore to circumvent these problems, several modified PVTa

system designs [5] with multiple passes of air, glazed back surface, use of extended surfaces

(fins), staggered plates, corrugated groves, hexagonal honeycomb structures have been explored to augment heat transfer from the heated surface of PV to the extracting medium i.e., air. The literature on these modified PVTa system designs to augment the exit temperature of air will be briefly reviewed in this introduction section. Solar air heating (SAH) system is a single kind of technology that uses solar energy for air heating only and hence the literature review on the topicof SAH is excluded in this article.

Tripanagnostopoulos [6] have tested low cost design alterations involving ribbed channel,corrugated sheet and tubes inside the channel for the generation of flow turbulence to intensify heat transfer rate to the air passing inside air channel. They recommended that these low cost alterations were suitable for thermal applications involving warm air. A double-pass PVTa system integrated with fin was considered for its performance evaluation by Othman et al. [7].In this design, the air was first heated during the first pass consisted of upper air passage betweenthe top glass cover and PV front surface by the direct sun rays. Then, the heat transfer rate to the air was increased in the second pass constituted by the lower air passage between the PV back surface with fins and a duct. For air mass flow rates of 0.05 kg/s and 0.1 kg/s, the maximum temperature rise was about 8°C and 2°C respectively. Modifications of air channel with the presence of thin sheet of metal (TMS) and protruding metal sheets (fins) from PV rear surface into the air channel were implemented by Tonui and Tripanagnostopoulos [8]. These modifications reduced the temperature of PV surfaces by 4°C to 10°C when compared to those obtained with the absence of such modifications.

The influence of PV solar cell encapsulation between glass & tedlar, and glass & glass structures in PVTa systems was analyzed by Dubey et al. [9]. Their results revealed that the glass & glass encapsulation produced better air exit temperature and electrical efficiency. The effect of

series and parallel combination of PV panels for building integrated PVT systems has been evaluated by Agrawal and Tiwari [10]. It was observed that the series combination of PV panels with constant air flow rate would be more suitable for the building integrated PVT systems.

The performance of PVTa systems having bifacial solar cells was investigated by Ooshaksaraei et al. [11] with alterations in air pass configuration and direction of air flow. They observed that the double air pass configuration in parallel flow exhibited the maximum thermoelectric efficiency. The lowest thermoelectric efficiency was obtained with a single pass PVTa system. The thermoelectric efficiency was within these limits for the case of a double passwith counter flow and returning flow PVTa system. Performance of PVTa system with segmented plates positioned in staggered fashion involving radiation heat transfer was determined by Ali et al. [12]. It was revealed that augmented heat transfer between air and staggered segmented plates could be possible with a wise choice of thickness and length of the segmented plates. The augmentation in heat transfer was due to the disruption in the development of thermal boundary layers and mixing of air. The testing on hybrid PVTa system with single and double duct, and having single and double air passes was carried out by Amori and Abd-Al Raheem [13]. It was established that PVTa collector design with double duct with single pass was suitable for PVTa application.

The heat transfer to flowing air in PVTa system was enhanced by Hussain et al. [14] with a hexagonal shaped honeycomb structured heat exchanger. The heat exchanger was placed in an adjacent parallel plane along the direction of air flow under the PV module. This arrangement resulted in a 60% enhancement in heat energy extraction. Greater contact surface of the honeycomb configuration was believed for the improved heat withdrawal rate from the panel rear side to the flowing air. Shyam and Tiwari [15] placed semitransparent solar PV module at the initial and later portions of the flow passage in PVTa system to study their effects in raising the air delivery temperature. They observed that the use of semitransparent solar PV module delivered air at outlet temperatures between 80 and 120°C. It was also recommended to use semitransparent solar PV module in the initial portions for better overall performance rather placing in the outlet portions.

Sahota and Tiwari [16] reviewed the implications of connecting a number of PV collectors (N) in series for various potential renewable energy applications. Consolidated optimal operating conditions specific to a renewable energy application with N-PVT systems weresummarized to help the practicing engineers. Thermal modeling was proposed for a conventionalPVT and thermoelectric cooler (TEC) coupled PVT with semi-transparent photovoltaic panel, and examined by Dimiri et al. [17]. The comparative analysis indicated that the electrical performance of TEC-PVT system was better than those of TEC- PV and conventional PVT.

PVTa system having longitudinal straight fins extending from PV panel surface was devised by Fan et al. [18] which provided air exit temperatures in the order of 60 to 90°C. With optimized value of fin parameters, this PVTa device produced excellent thermal performance even under varying climatic situations and roof tilt angle [19]. Barone et al. [20] developed a new and cheap PVTa system by overlapping 2 galvanized commercial roof sheets to form hexoganol shaped air ducts. Individual low cost DC fans were used as the source of air flow. They tested the performance of this novel PVTa system for different air mass flow rates, surface tilt angles and climatic situations. The DC fans consumed a maximum of 195 kWh per year which was equal to 1.76 % of the electricity produced by the PVT system.

Recently, W u et al. [21] investigated numerically the effect of air channel position on thethermoelectric performance of PVTa systems. 2 channel positions were considered, namely, one

above and the other below PV panel. It was concluded that the first case was better than the second one in terms of thermal performance due to the effect of internal radiation in the air channel. However, the first case offered poor electrical efficiency as a result of poor PV cooling effect. An opposite behavior was observed with the second case.

Dimri et al. [22] used artificial neural network (ANN) technique to predict thermal and electrical performance of glass-tedler PVT system coupled with TEC. A very good correlation coefficient in the order of 0.99 was observed between the experimental and predicted parameters.The effect of working fluids namely air and water on the performance of TEC-PVT with opaque PV panel was also reported by Dimiri et al. [23]. They also reported the influence of base cover material on TEC-PVT performance. ANN prediction model was also developed and an acceptable agreement between the experimental and predicted results was noticed. A book was explicitly devoted by Tiwari and Dubey [24] for catering the need of students, learners, scientists, professionals, practitioners and designers in the field of PVT systems. The book discussed the history of PVT air systems and the use of artificial intelligence techniques to determine their performance in addition to several other aspects of fundamental, research and mathematical modeling related to PVT technology.It is important to take notice of the fact that, in a closed conduit flow, the fluid will have a characteristic of developing flow in the upstream portion of the passage/channel flows with high heat transfer rates. Upon the development of flow in thedownstream portion of passage/channel, heat transfer rates will be lower and have constant values. This is because the driving temperature gradient between the hot surface and fluid is highat the entrance or the leading portions where the flow is developing, Thereafter, due to heating ofair inside the channel as it flows, this driving temperature difference decreases and hence theheat transfer is reduced in the trailing portions where the flow is fully developed. Literature scan on PVTa performance improvement shows that the suggested design alterations were done for the entire air channel length which had

(i) Constant surface or contact area for the air from entrance to the exit to effect heat transfer from the heated PV surface.

(ii) Higher pumping power due to high frictional resistance and

(iii) Higher system weight with higher costs of manufacturing, operating and transportation [6].

For the above negating reasons, it is suggested for using a PVTa channel with partial length heat exchanger enhancement design in place of a full length enhancement design. A comprehensive summary of design alterations made by the researchers in the design of PVT air channel over the last decade is presented in Table 2 from which it is understood that the performance of PVTa system with longitudinal and wavy fins in the downstream side of the air channel had not been researched. Hence in this work, the effect of introducing fins (longitudinal and wavy) in the downstream section of the air channel was explored experimentally in Tiruchirappalli city, state of Tamilnadu in India for the year of 2018 from the month of June to

September. The PV surface temperature, air temperatures at channel inlet/outlet and electrical measurements were recorded using an indigenously assembled PV data monitoring system with ATmega2560 microcontroller. A FL model was developed for the prediction of solar PVTa collector power yield and air outlet temperature.

Experimental system

The experimental system had 2 flat polycrystalline solar PV modules assembled from parallel connected 5 Wp panels (Synergy solar Ltd., India). Among the two, one set of panel wasused as a reference PV while the other set was used as PVTa system, and they were placed side by side over supporting frames kept inclined 23^{o} to the ground and sloping downwards to south. For PVTa system, a 156 x 156 x 1980 mm air channel was built from galvanized iron (GI) sheets of 1 mm thickness. An independent 50 W solar PV panel was utilized to operate the DC fan to allow air flow in the air channel. An insulation having a thickness of 19 mm was maintained on the external surfaces of the air channel to prevent heat transfer between the atmosphere and air in the channel. The experimental test facility is shown in Fig. 1.

At any particular section, the air temperature will vary as it heated from the top by the PVpanel surface. Hence, the air temperature will be higher in the vicinity of PV panel when compared to the air in the vicinity of bottom surface of the air duct. In addition, air temperature profiles near the side walls of air duct will also be different. Therefore to account all of these effects and to improve on the reliability of air temperature measurements at inlet and outlet, 1BMP180 sensor was placed in the middle of the air duct and 3 LM35 sensors were fixed to the2 side walls and 1 bottom surface of the air duct (Fig. 2). The air temperature in the proximity of PV panel was assumed equal to that of panel temperature. The air temperature at the inlet and

outlet section was then estimated by averaging the measurements of 1BMP180 sensor at the middle, 3 LM35 sensors located at bottom and side walls, and 1 LM35 sensor fixed to PV panel.

Using the values of flow Reynolds number (Re), hydraulic diameter (D_h) and other fluid properties (air density and viscosity), the entrance length could be estimated theoretically where the hydrodynamic boundary layer grows with increasing thickness and the flow is to be developing. Under practical considerations, this entrance length ceases approximately at a distance equal to 10 times the hydraulic diameter. With this knowledge, it was estimated that the flow becomes fully developed at a distance of 1500 mm form the leading edge for the present work. As the total length of the duct for the present work is 1980 mm, the flow becomes fully developed during the final duct length of 480 mm. The portion for a duct length of around 920 mm in the second half of the duct where the fins were mounted was considered as downstream for this work. Hence for experimenting PVTa system with fins, 3 longitudinal fins (PVTa-L) made from 1x102 x 920 mm GI sheets were positioned at an interval of 39 mm in the downstream portion of the channel for a length of 920 mm. 3 wavy fins (PVTa-W) were also fabricated from 1x102 x 920 mm GI sheets and were placed in the downstream portion of the channel. The wavy fins had wave amplitude of 19.05 mm and a pitch of 332.74 mm for whichthe effective length of the wavy fins was 907.54 mm. The fins were affixed to the tedler side of the PV panel with commercial silicone thermal grease. The details of the longitudinal and wavy fins were given in Fig. 3(a) and 3(b) respectively.

Table 1 Summary of literature on design alterations in air channel of PVTa system

Reference	Year	Alterations in PVTa air channel design
Tripanagnostopoulos [6]	2007	Channel with • Ribs • Corrugated sheet • Tubes
Othman et al. [7]	2007	• 2 air passes • First pass between glass and PV • Second pass with finned duct below PV
Tonui and Tripanagnostopoulos [8]	2008	• Thin sheet of metal (TMS) • Protruding metal sheets (fins)
Dubey et al. [9]	2009	• Channel with PV glass & tedlar • Channel with PV glass & glass
Agrawal and Tiwari [10]	2010	• Series and parallel connected PV panels forBIPVT systems
Ooshaksaraei et al. [11]	2013	• Channel with Bifacial solar cells
Ali et al. [12]	2013	• Channel with staggered segmented plates
Amori and Abd-AlRaheem [13]	2014	• Channel with single or double duct • Channel with single or double air pass
Hussain et al. [14]	2015	• Channel with hexagonal shaped honeycomb structured heat exchanger
Shyam and Tiwari [15]	2016	• Air channel with semitransparent PV panelin serial connection
Sahota and Tiwari [16]	2017	• number of collectors (N) in series i.e, N-PVT systems
Dimiri et al. [17]	2017	• Semi-transparent PV panel withthermoelectric cooler
Fan et al. [18,19]	2017,2018	• Optimization of fin parameters
Barone et al. [20]	2019	• Hexagonal shaped air ducts
W u et al. [21]	2019	• Air channel above and below PV panel
Dimiri et al. [22, 23]	2019	• Glass tedlar and opaque PV panel withthermoelectric cooler

Present study	2020	• Air channel with longitudinal and Wavyfins in the downstream side

International Journal of Engineering, Science and Mathematics
Vol. 7 Issue 10, October 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

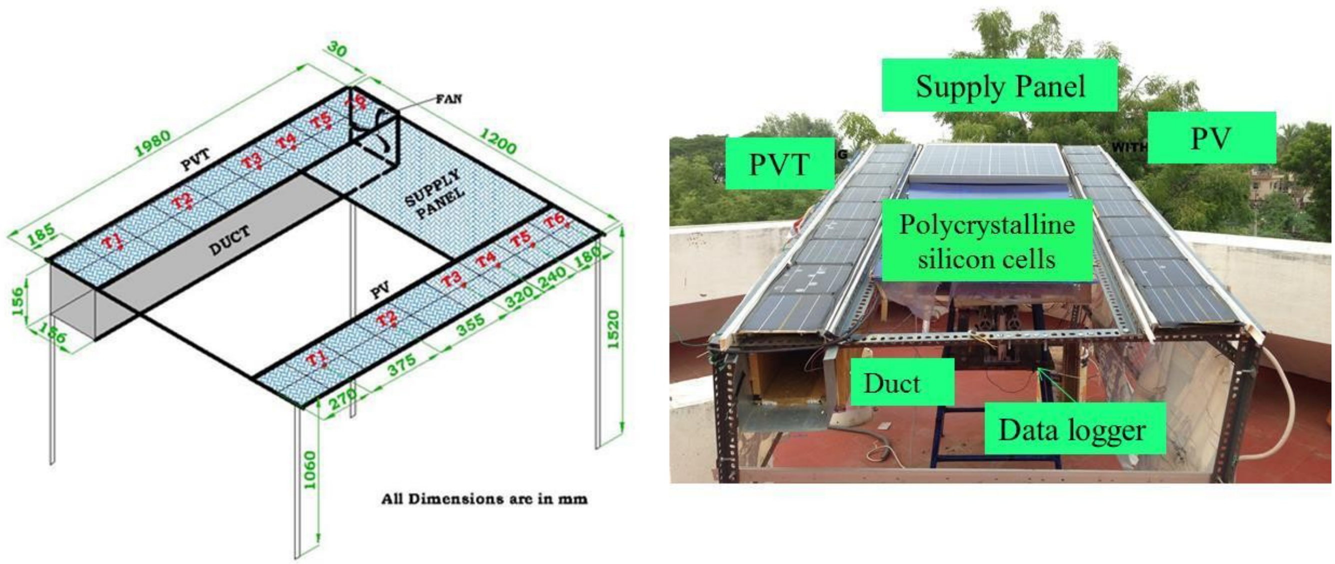


Fig. 1 Experimental setup

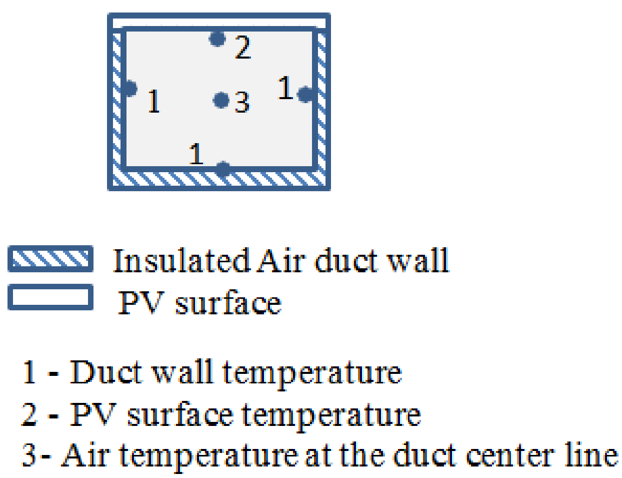


Fig. 2 Senosr location details for air temperature measurement

International Journal of Engineering, Science and Mathematics
Vol. 7 Issue 10, October 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

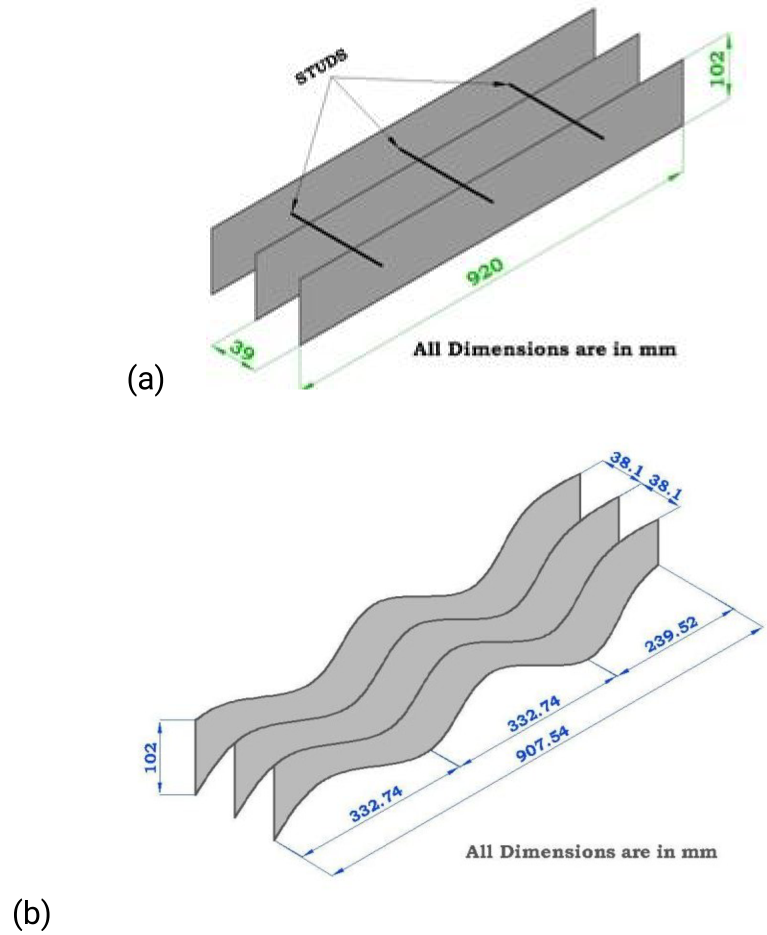


Fig. 3 (a) Longitudinal fins (b) Wavy fins

A data logging unit was assembled in-house with ATmega2560 microcontroller for acquiring thermal characteristics (panel surface temperature, air temperatures at the entrance and exit of the air passage) and the electrical characteristics (PV current and PV voltage). LM 35 sensors measured the panel temperatures in PV and PVTa systems which were fastened to the rear side of the PV panel at a distance of 270, 645, 1000, 1560 and 1740 mm from the upstream edge (Fig. 1). The average of these temperatures was represented as PV panel temperature in this work. BMP180 pressure sensors were utilized for acquiring centerline air temperature at inlet and outlet of the air channel. Variable rheostats having a resistance of 0 to 28 Ω were used as loading device for each of the PV module. A programmed microcontroller automated the movement of a common slider for both rheostats by an in-house designed lead screw arrangement which was operated by a heavy duty 12V DC motor. The details related to the indigenously assembled PVT data acquisition unit were provided in our previous work [35]. The solar radiation intensity was measured on the titled plane surface that is parallel to PV panelusing a solar pyranometer having a measurement range upto1800 W/m^2 with an accuracy level of ±5% on full scale reading.

The quantitative and qualitative performance analysis of the 2 different PVT configurations considered in this work was done form energy and exergy point of view respectively. The gain in low grade thermal and high grade electrical energy was estimated using the following equations [22, 23]

$$E_{th} = \dot{m}_a \, c_p (T_{out} - T_{in}) \tag{1}$$

$$E_{el} = VI \tag{2}$$

The gain in high grade thermal energy i.e, thermal exergy was determined using the following equation [24]

$$Ex_{th} = \dot{m}_a \, c_p \left\{ (T_{out} - T_{in}) - (T_a + 273) ln \left(\frac{T_{out} + 273}{T_{in} + 273} \right) \right\} \tag{3}$$

To ensure repeatability of the instruments, repeated measurements on variables liketemperature, PV current, PV voltage and intensity of solar radiation were observed. A

International Journal of Engineering, Science and Mathematics
Vol. 7 Issue 10, October 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

numerical mean of these measurements were then calculated and compared with the actual measurements. The maximum deviation from the mean is then related to the experimental measurement error. Inthis work, the measured independent variables like temperature, PV current, PV voltage and solar intensity had a deviation in the limits of ± 0.2°C, ± 0.02 A, ± 0.1 V and ± 20 W/m^2 respectively. The uncertainty in power produced which is a dependent variable was calculated using propagation law as ± 0.1%.

Results and Discussion

With the experimental facility discussed in section 2 with wavy fins, experiments were conducted from 10 AM to 2 PM on some days in the year of 2018 for tenure of 3 months (June- August). The average of the experimentally obtained values of solar radiation, entry and exit air temperatures, PV panel temperatures and the power developed for these 3 months was depictedin Fig. 5. Similarly, the experimental results obtained for 3 months (June- August) with

longitudinal fins were presented in Fig. 6. The change in climatic parameters namely the solar radiation and ambient temperature varied substantially during these 3 months of time span which could not be ignored. To account the changes in the climatic parameters, a normalization technique with the following assumptions was adopted so as to compare the performance of PVTa-W and PVTa-L system on a common scale.

International Journal of Engineering, Science and Mathematics
Vol. 7 Issue 10, October 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

- The temperature rise of air is a function of inlet air or the ambient temperature and panel temperature. Ambient temperature at a standard condition of 25°C was used for normalization.
- The panel temperature is a function of solar radiation for which a value of 1000 W/m^2 was used for normalization.

With the above assumptions, the normalized values for the temperature rise of air and the panel temperature was determined using Eq. (6) and Eq. (7)

$$\Delta T^* = \frac{(T_{Out} - T_{In})}{T_{In}} \times 25 \quad (6)$$

$$T_P^* = \frac{T_P}{G} \times 1000 \quad (7)$$

As the data set is very large, standard deviation (s) was calculated and found as 65 W/m^2, 3°C, 4°C and 1 W for solar radiation, air inlet and outlet temperatures, PV panel temperaturesand the power respectively for the 3 months of experimental values. Based on the arithmetic mean, standard deviation and the number of data set (n), the deviation (u) in the mean value of experimental values could be reported as $u = \frac{s}{\sqrt{n}}$. Here 's' is the standard deviation of a particular data set. Thus, the deviation in the measurement of temperature, power and solar

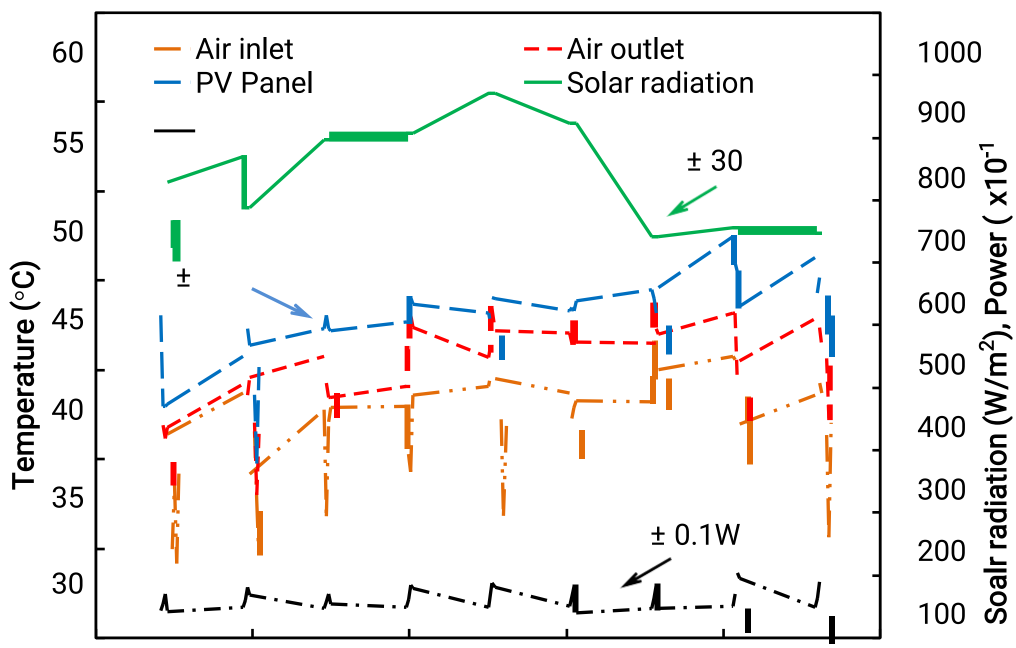
radiation due to weather conditions were found to be ± 0.05°C ± 0.1 W and ± 30 W/m^2 respectively.

The abrupt discontinuity in the experimental values at regular intervals in Fig. 5 and 6 was due to the changes in rheostat loading conditions controlled by a programmed microcontroller as discussed in section 2. It is evident that a maximum of 5°C and 3°C difference between the entry and exit air temperature was observed for PVTa with wavy and longitudinal fins respectively. The maximum of the average panel temperatures were in the order of 45°C and 40°C while the average power developed was less than and above 5 W for wavy and longitudinal fins respectively. The solar radiation changed in the range of 650-900 W/m^2 while experimenting with both PVTa systems. The average values of normalized air temperature rise and the normalized panel temperature for PVTa-W system was estimated as 1.96°C and 58.9°C respectively which indicates that a 0.04°C normalized air temperature rise would be possible per 1°C normalized panel temperature (i.e.,=1.96/58.9). Similarly for PVTa-L, the average values of normalized air temperature rise and the normalized panel temperature for PVTa-L system was estimated as 0.90°C and 49.6°C respectively which indicates that a 0.02°C normalized air temperature rise would be possible per 1°C normalized panel temperature. Thus the results suggest that normalized air temperature rise was 0.04°C and 0.02°C for wavy and longitudinal fins respectively which confirm that the fact that wavy fins resulted in higher outlet air temperature when compared to those with longitudinal fins. The reason for enhanced air outlet temperature with wavy fins could

International Journal of Engineering, Science and Mathematics
Vol. 7 Issue 10, October 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

be related to phenomenon of mixing and the associatedturbulence in the downstream section of the channel.

A comparison of results of quantitative and qualitative performance obtained with PVTa, PVTa with longitudinal and wavy fins in terms of daily average thermal energy, electrical energyand thermal exergy was shown in Fig. 7. The error bar indicates that fluctuations in their value due to the solar intensity variations during the 6 months duration. The effect of wavy fin in PVT system could be again manifested with the highest values of energy (both thermal and electrical) and thermal exergy. Further, it is observed that the conventional PVT air system had the lowest values which justified the proposed idea of using fins in the downstream side of the air channel for performance improvement.



International Journal of Engineering, Science and Mathematics
Vol. 7 Issue 10, October 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

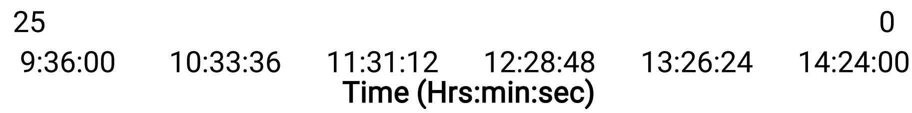


Fig. 5 Experimental results obtained with PVTa-W

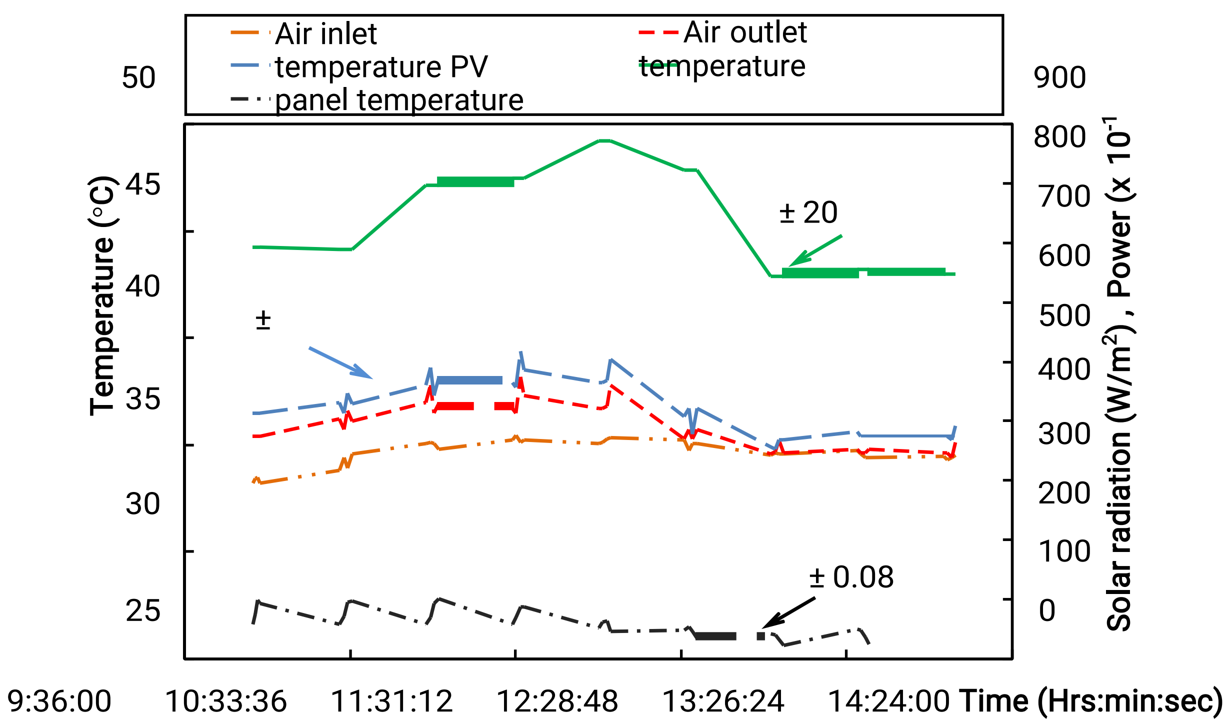
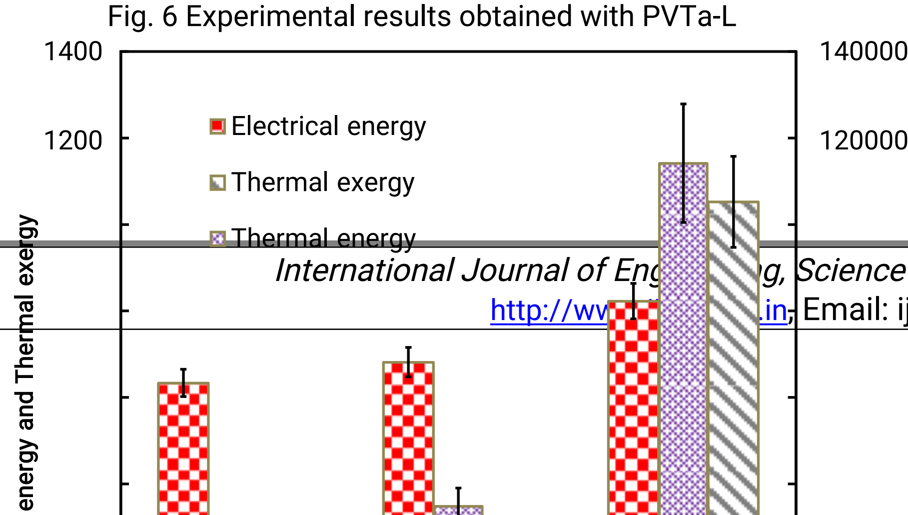


Fig. 6 Experimental results obtained with PVTa-L



International Journal of Engineering, Science and Mathematics
Vol. 7 Issue 10, October 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

Fig. 7 Daily average thermal energy, electrical energy and thermal exergy

Conclusions

This article reported the experimental performance of solar PVTa systems with longitudinal and wavy fins on the downstream portion of the collector passage for the year of 2018 in the locality of Tiruchirappalli of Tamilnadu in India. The results indicated that PVT system with wavy fins performed better than PVT with longitudinal fins. The reason for enhanced energy and exergy performance with wavy fins in the downstream section of the air channel was attributed due to the phenomenon of mixing and the associated turbulence. The mean of the experimental values were used by the fuzzy logic system to predict the performance of these PVTa systems. The outcomes of the present work were summarized below.

(i) The experimental findings indicated that PVTa device with wavy fins had better thermal performance than the PVTa device with longitudinal fins in terms of air outlet temperature. This fact was supported by normalized values of air outlet temperature and panel temperature.

(ii) The experimental panel temperatures were in the order of 45°C and 40°C, while the average power developed was less than and above 5 W for wavy and longitudinal finsrespectively.

References

[1] R. Kumar, M. A. Rosen, A critical review of photovoltaic–thermal solar collectors for airheating Applied Energy 88 (2011) 3603–3614

[2] W. Pang, Y. Cui, Q. Zhang, G.J. Wilson, H. Yan, A comparative analysis onperformances of flat plate photovoltaic/thermal collectors in view of operating media, structural designs, and climate conditions Renewable and Sustainable Energy Reviews119 (2020) 109599.

[3] S. Preet, Water and phase change material based photovoltaic thermal managementsystems: A review, Renewable and Sustainable Energy Reviews 82 (2018) 791–807.

[4] A. M. Elsafi, P. Gandhidasan, Comparative study of double-pass flat and compound parabolic concentrated photovoltaic–thermal systems with and without fins, Energy Conversion and Management 98 (2015) 59–68

[5] J.J. Michael, S. Iniyan, R. Goic, Flat plate solar photovoltaic–thermal (PV/T) systems: A reference guide, Renewable and Sustainable Energy Reviews 51 (2015) 62–88

[6] Y. Tripanagnostopoulos, Aspects and improvements of hybrid photovoltaic/thermal solar energy systems, Sol. Energy 81 (2007) 1117–1131.

[7] M. Y. Othman, B. Yatim, K. Sopian, M. N.AbuBakara, Performance studies on a finned double-

pass photovoltaic-thermal (PV/T) solar collector, Desalination 209 (2007) 43–49.

[8] J.K. Tonui, Y. Tripanagnostopoulos, Performance improvement of PV/T solar collectors with natural air flow operation, Sol. Energy 2008; 82:1–12.

[9] S. Dubey, G.S. Sandhu, G.N. Tiwari, Analytical expression for electrical efficiency of PV/T hybrid air collector, Appl. Energy 86 (2009) 697–705.

[10] B. Agrawal, G.N. Tiwari, Optimizing the energy and exergy of building integrated photovoltaic thermal (BIPVT) systems under cold climatic conditions, Appl. Energy87(2) (2010) 417–426.

[11] P. Ooshaksaraei, K. Sopian, R. Zulkifli, S.H. Zaidi, Characterization of air-based photovoltaic thermal panels with bifacial solar cells, Int. J. Photoenergy, volume 2013, Article ID 978234, 10 pages, http://dx.doi.org/10.1155/2013/978234

[12] A.H.H. Ali, M. Ahmed, S.M. Abdel Gaied, Investigation of heat transfer and fluid flow in transitional regime inside a channel with staggered plates heated by radiation for PV/T system, Energy 59 (2013) 255-264.

[13] K.E. Amori, M.A. Abd-Al Raheem, Field study of various air based photovoltaic/thermal hybrid solar collectors, Renew. Energy 63 (2014) 402-414.

[14] F. Hussain, M.Y.H. Othman, B. Yatim, H. Ruslanb, K. Sopian, Z. Anuar, S. Khairuddin, An improved design of photovoltaic/thermal solar collector, Sol. Energy 122 (2015) 885–891.

[15] Shyam, G.N. Tiwari, Analysis of series connected photovoltaic thermal air collectors partially covered by semitransparent photovoltaic module, Sol. Energy 137 (2016) 452– 462.

[16] L. Sahota, G. N. Tiwari, Review on series connected photovoltaic thermal (PVT) systems: Analytical and experimental studies, Sol. Energy150 (2017) 96-127.

[17] N. Dimri, A. Tiwari, G. N. Tiwari, Thermal modelling of semitransparent photovoltaic thermal (PVT) with thermoelectric cooler (TEC) collector, Energy Conversion and Management, Volume 146, 15 August 2017, Pages 68-77

[18] W. Fan, G. Kokogiannakis, Z. Ma, P. Cooper, Development of a dynamic model for a hybrid photovoltaic thermal collector Solar air heater with fins, Renew. Energy 101 (2017) 816-834.

[19] W. Fan, G. Kokogiannakis, Z. Ma, A multi-objective design optimisation strategy for hybrid photovoltaic thermal collector (PVTA)-solar air heater (SAH) systems with fins, Sol. Energy 163 (2018) 315–328.

[20] G. Barone, A. Buonomano, C. Forzano, A. Palombo, O. Panagopoulos, Experimentation, modelling and applications of a novel low-cost air-based photovoltaic thermal collector prototype, Energy Conversion and Management 195 (2019) 1079–1097.

[21] S.Y. Wu, T. Wang, L. Xiao, Z.G. Shen Effect of cooling channel position on heat transfer characteristics and thermoelectric performance of air-cooled PV/T system Solar Energy Solar Energy 180 (2019) 489–500

[22] N.Dimri, A.Tiwari, G. N. Tiwari, An overall exergy analysis of glass-tedlar photovoltaic thermal air collector incorporating thermoelectric cooler: A comparative study using artificial neural networks, Energy Conversion and Management, 195(1)(2019) 1350-1358.

[23] N. Dimri, A. Tiwari, G. N. Tiwari, Comparative study of photovoltaic thermal (PVT) integrated thermoelectric cooler (TEC) fluid collectors, Renewable Energy134 (2019) 343-356.

[24] G. N. Tiwari, S. Dubey, Fundamentals of photovoltaic modules and their Applications, Royal Society of Chemistry (RSC), (UK), 2010.

[25] M. Sridharan, Predicting performance of double pipe parallel and counter flow heat exchanger using fuzzy logic, J. Thermal Sci. Eng. Appl. 12(3) (2020) 1-11.

International Journal of Engineering, Science and Mathematics
Vol. 7 Issue 10, October 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A