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APPLICATION OF BAFFLE PLATES AND ITS EFFECTS AS LOW COST HEAT EXTRACTION IMPROVEMENT ON THE PERFORMANCE OF PHOTOVOLTAIC THERMAL SYSTEM (PVT)

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ABSTRACT

In this paper an experimental analysis on the performance of photovoltaic thermal system with two different configurations under the composite climate of Bhopal have been evaluated.For this evaluation two different configurations (type A and type B) of commercially available PVT modules have been installed and tested at the National Institute of Technology Bhopal(NIT, Bhopal). The type A PVT module comprises monocrystalline Si solar cells integrated with an air channel at the rear side of PV module for the air flow as a heat extraction unit, while the type B PVT module integrated with the baffle plates inside the air channel to generate the laminar air flow. The experiments have been performed at two different mass flow rates of air (0.052 kg/sec and 0.104 kg/sec) under clear weather conditions. It has been found that the average thermal efficiency and electrical efficiency for the type A PVT modules are 40.7% and 11.8%, respectively, and those for the type B PVT module are 39.4% and 11.5%, respectively.

KEYWORDS: Thermal performance; Electrical performance; laminar and turbulent air flow; thermal collector**.**

1. INTRODUCTION

Hybrid Photovoltaic thermal technology draws the more attention of many researchers in recent decades, and PVT system performances has been evaluated and analyzed by several researchers. As Tiwari A and Sodha M.S.[1] evaluate the overall performance of hybrid PV/thermal (PV/T) air collector for different configurations of hybrid air collectors which are considered as unglazed and glazed PV/T air heaters, with and without tedlar. They have been derived analytical expressions for the temperatures of solar cells, back surface of the module, outlet air and the rate of extraction of useful thermal energy from hybrid PV/T air collectors. Rajendra Karwa et.al[2] presents an experimental investigation of the performance of solar air heaters with chamfered repeated rib-roughness on the airflow side of the absorber plates. They found that the roughened elements have a relative roughness pitch of 4.58 and 7.09 while the rib chamfer angle is fixed at 15°. For the airflow duct depths of 21.8, 21.5 and 16 mm, the relative roughness heights for the three roughened plates used are 0.0197, 0.0256 and 0.0441, respectively. The study shows substantial enhancement in thermal efficiency (10 to 40%) over solar air heaters with smooth absorber plates due to the enhancement in the Nusselt number (50% to 120%). The thermal efficiency enhancement is also accompanied by a considerable enhancement in the pumping power requirement due to the increase in the friction factor (80% to 290%). H.P.Garg and R.S.Adhikari[3] investigated, a computer simulation model for the analysis of a solar photovoltaic/thermal (PV/T) hybrid collector, with air as heat transfer fluid and algorithm for making quantitative prediction regarding the performance of the system is described.Thermal efficiency curves for the solar PV/T hybrid collectors corresponding to various type of absorbers have been derived. Swapnil Dubey et.al.[4] worked on the combined system of photovoltaic thermal(PV/T) solar water heater system. The designed system with solar water heater of capacity 200 l was tested in outdoor condition for composite climate of New Delhi. They considered three cases by covering or uncovering the absorber from photovoltaic module. They observed that the photovoltaic thermal (PV/T) flat plate collector partially(30.56%)covered with PV module gives better thermal and average cell efficiency which was in accordance with the results reported by earlier researchers. Y. Tripanagnostopoulos et al.[5-6] worked alot from 2000 to till date, on the performance, modeling, design modifications and parametric studies of the photovoltaic thermal system to the best of author’s knowledge. They have used the Thin metallic sheet (TMS), Fins at the back of PV panel to improve the cooling of the PV panel. They found that the efficiency with fins arrangement is more than the TMS arrangement. They have extended their experiment for the same module and same configuration but for the different combinations using glazed and unglazed surface for the all three configurations. They observed that the additional glazing improves the heat production but lowers the electrical efficiency of a PV/T collector under the immensed solar insolation. Infield et al.[7] have been used the double glass wall with PV module for flowing air between them in order to reduce the temperature of the PV module, space heating can be done with this thermal energy. They have also developed a steady-state model to evaluate an overall heat loss coefficient and thermal gain factor. Zondag et al.[8] and Tripanagnostopoulos et al.[9] have been carried out the similar studies to reduce the temperature of the PV module they have applied air and water as heat extraction options at the back surface of the the PV module to reduce the temperature and increase the electrical efficiency of the system. Amin Elsafi[10] the steady-state performance evaluation of a double-pass flat plate hybrid photovoltaic/thermal (PV/T) solar heater with attached vertical fins of different configurations at the bottom of the absorber in the lower channel has been evaluated.The simulation results showed that the use of pin fins is beneficial to achieve better performance over the design with straight fins. Aste et al.[11] reported that the PV/T solar air heater draws more attention of the researchers due the lower heat capacity of the air compared with water, the heat transfer process is comparatively slow. Till date, very few studies have been carried out on monocrystalline PVT systems with low cost modification for production of both electricity and hot air.This paper describes the experimental analysis of PVT modules under the climatic conditions of Bhopal using heat extraction designs improvement as baffle plates at the rear side of PV modules in the air chamber.

2. EXPERIMENTAL SETUP AND INSTRUMENTATION

An experimental set up consists of two commercially available monocrystalline photovoltraic module with power rating of 36Wpshown in fig 1.The PVT modules were mounted over stainless steel frame as shown in fig.2(a) and(b) In the experimentation two configurations have been used namely type A and type B. The type A PVT module comprises with an air channel at the rear side of PV module for the turbulent air flow as a heat extraction unit, while the type B PVT module integrated with the baffle plates inside the air channel to generate the laminar air flow. Bhopal is at latitude 23° 30'; however the modules were kept in the east-west during experiment to extract maximum advantage of incident solar radiation. The PV/T collector is inclined with 23°. Two DC fans were used to supply air into air duct which were operated by battery. The circulation of air under the PV panels helps to reduce the temperature of the PV cells and hence increase the PV efficiency. To measure the inlet, and outlet air temperature, and temperature across the different layers in the PVT modules, calibrated with standard zeal thermometer to ensure the accuracy.Thermo-hygro meter & infrared thermometer have been used. Solar radiation has been measured using a precision solar power meter. A hot wire anemometer has been used to measure the air flow at different locations, i.e., air inlet & outlet of the duct and surface over the PV module. Multimeter has been used to measure the open circuit voltage. Ammeter is attached in series to the PV and charge controller to measure the PV module generated current.

The data were measured from 10:00 to 17:00 hrs during April and May 2014. The measured data include the solar radiation intensity, ambient temperature, inlet and outlet air temperature, solar cell temperature, inlet air velocity, open-circuit voltage, and short-circuit current.

Fig.1 PV module used for the experimentation

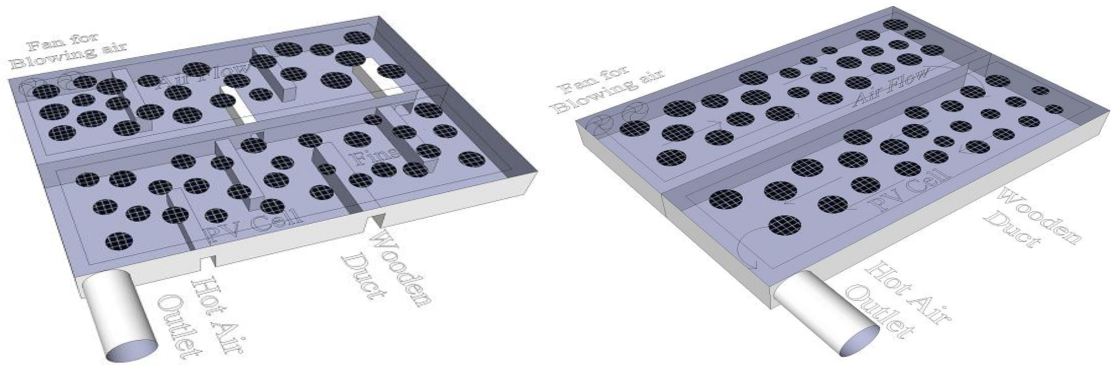
3. METHODOLOGY

Experiment was carried out with two different configurations namely Type A (with baffle plates for laminar flow) and Type B (without baffle plates for turbulent air flow)as shown in fig. Baffles were placed perpendicular to the direction of air flow at the rear side of PV panel into the air duct. Both the configurations were made with the same PV module with two different mass flow rates of 0.052 kg/sec and 0.104 kg/sec.

(a) (b)

Fig.2: Experimental set up with (a) baffle plates and (b) without baffle plates.

The schematic of the PV/T collector with and without baffle plates are shown in Fig. 3(a) and 3(b) respectively.



(a) **(b)**

Fig.3: The schematic of PV/T collector (a) with baffles (b) without baffle.

4. RESULT AND DISCUSSION

4.1. Type A (PVT without Baffle)

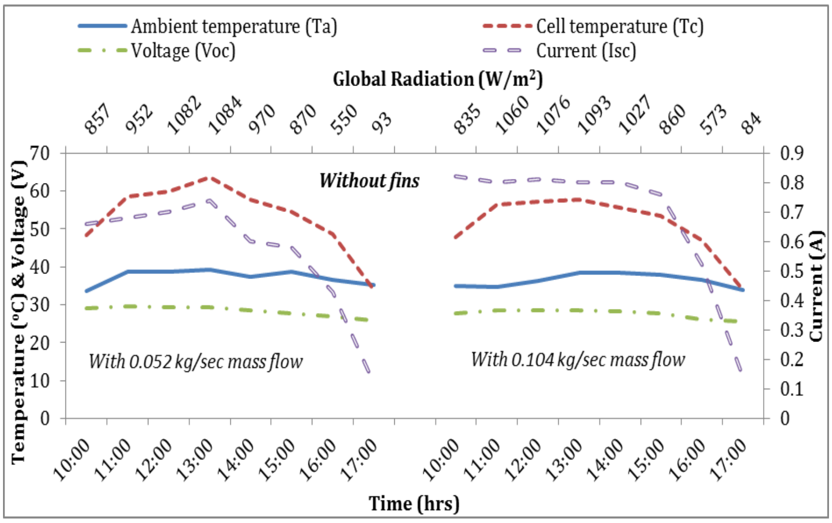


Fig.4.1. Variation of ambient temperature, cell temperature, voltage and current of PV/T system with respect to time and global solar radiation in case of without baffle

In the fig.4.1 variation of ambient temperature, cell temperature, voltage and current of PV/T system with respect to time and global solar radiation are shown in case of without baffle. It is observed that the ambient temperature and cell temperature increases from 10:00 hrs to13:00 hrs, and then decreases. It is also reported that the variation in voltage is less but the current varies significantly. The maximum and minimum values of current obtained in case of 0.052 kg/sec mass flow rate of air are 0.68 A and 0.12 A and 0.82 A and 0.14 A respectively in case of 0.104 kg/sec mass flow rate due to more heat is extracted from the PV module.

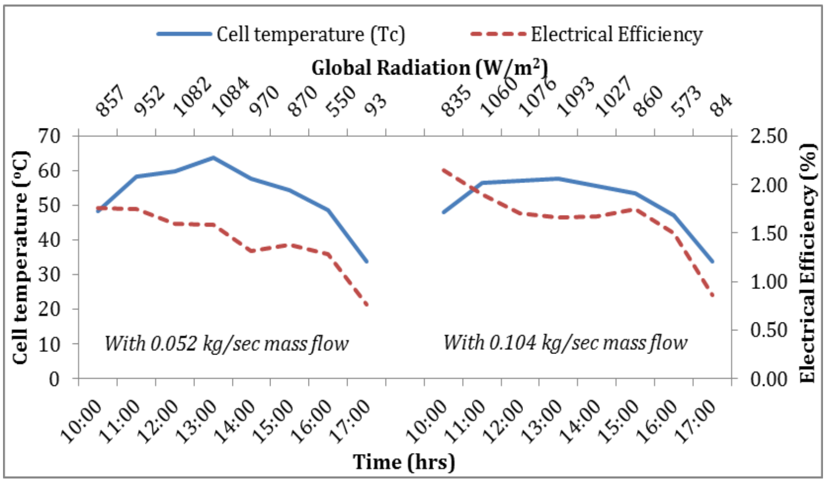


Fig.4.2. Variation of cell temperature and electrical efficiency of the PV/T system with respect to time and global radiation in case of without baffle

Effect of cell temperature on the electrical performance of the PVT system with respect to time and global radiation are shown in Fig.4.2.It has been observed that with the increase in the cell temperature the efficiency of the system is decreased. Furthermore the electrical efficiency of the PV/T system depends on cell temperature of the PV module, hence cooling of the system is required. Electrical efficiency of the PV/T system is quite high when mass flow rate of cooling air is 0.104 kg/sec as compared to 0.052 kg/sec. On an average of 16% of electrical efficiency of the PV system can be enhanced by increasing the air mass flow rate from 0.052 kg/sec to 0.104 kg/sec.

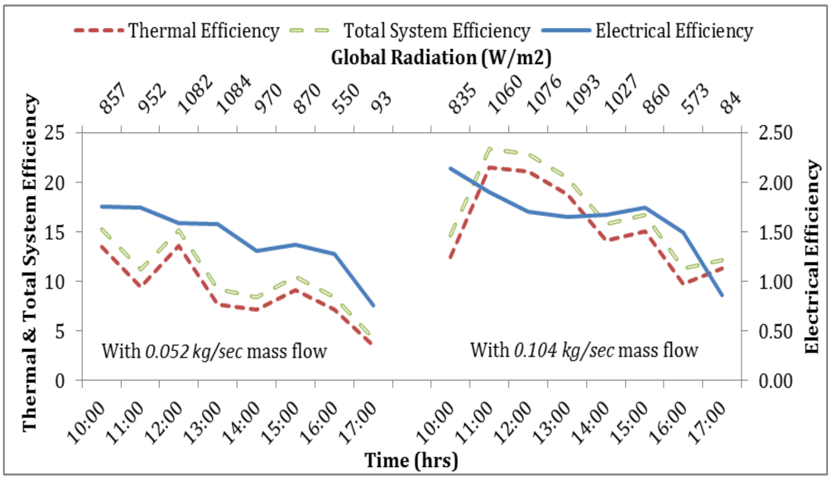


Fig.4.3. Variation of electrical, thermal and total efficiency of the PV/T system with respect to time and global radiation in case of without baffle

The electrical, thermal and overall efficiency of the PV/T collector without baffles are plotted in Fig.4.3. Both the electrical and thermal efficiency of the PV/T collector is found to be higher in case of 0.104 kg/sec mass flow rate.

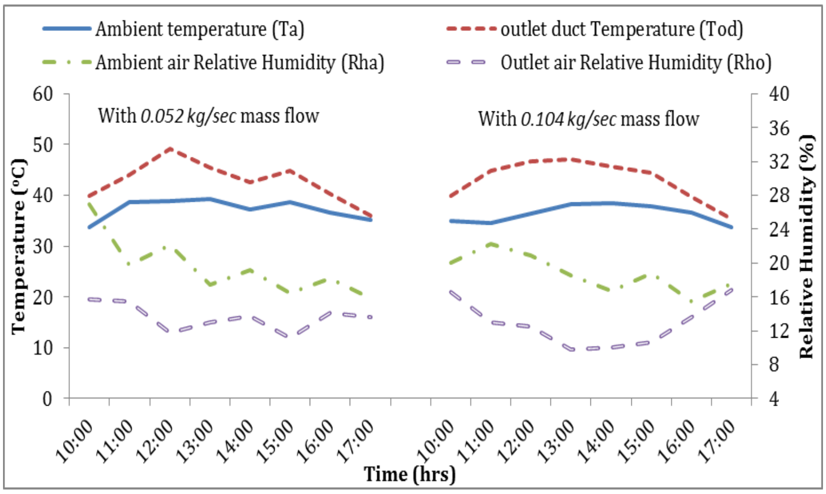


Fig.4.4. Comparison of ambient and outlet temperature, relative humidity with respect to time without baffle

Fig.4.4 shows the comparison of ambient and outlet temperature, relative humidity with respect to time. It has been observed that as the mass flow rate of the air increases from0.052kg/sec to 0.104 kg/sec, temperature of the outlet air decreases. It is due to more rapid extraction of heat as compared to lower mass flow rate of air. The average temperature of outlet air is 44 ^{o}C.

4.2. Type B (PVT with Baffle)

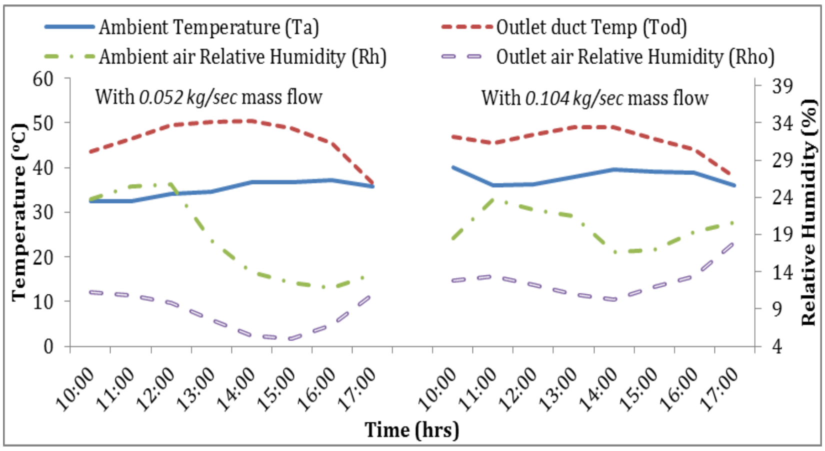


Fig.5.1. Comparison of ambient and outlet temperature, relative humidity with respect to time with baffles

Fig.5.1 shows the comparison of ambient and outlet air temperature, relative humidity with respect to time of the day in case of baffle plates. It has been observed that in case of 0.052 kg/sec mass flow rate the outlet duct temperature is more and the relative humidity is low as compared to 0.104 kg/sec mass flow. It has been reported that the baffles are more efficient for the extraction of heat from the PVT system with low mass flow rate.

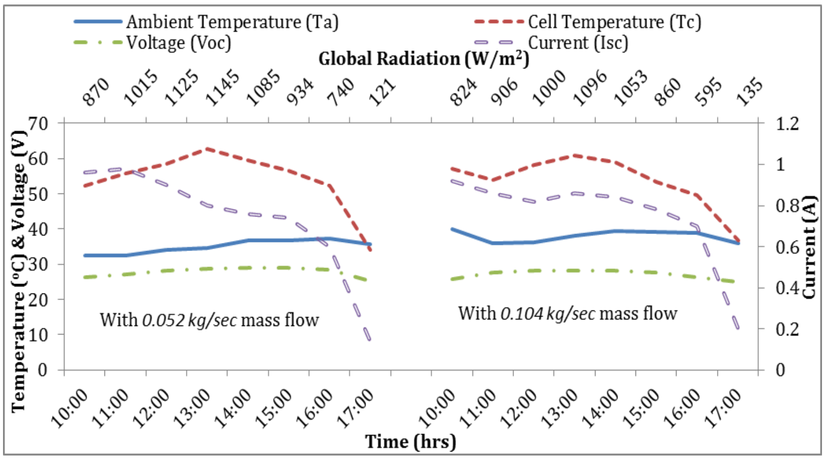


Fig.5.2. Variation of ambient temperature, cell temperature, voltage and current of PV/T system with respect to time and global solar radiation with baffles

The variation of ambient temperature, cell temperature voltage ,current and global radiation with respect to time have been shown in the fig.5.2.It has been observed that as the global radiation increases, and further temperature of the cell increases from 10:00 hrs till 13:00 hrs and then decreases. The values of voltage and current significantly increased by increasing the mass flow rate of from 0.052kg/sec to 0.104kg/sec. of air. The cell temperature of the PVT system is decreased by increasing the mass flow of air.

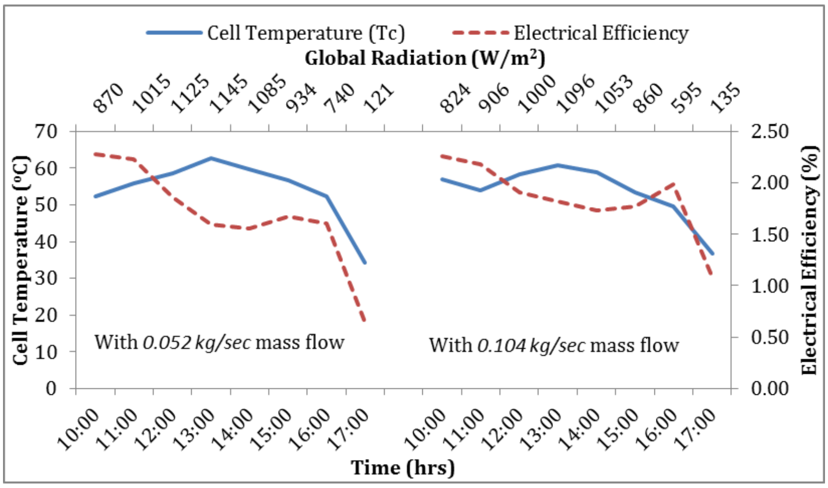


Fig.5.3. Variation of cell temperature and electrical efficiency of the PV/T system with respect to time and global radiation with baffles

The effect of cell temperature on the electrical performance of the PVT system with two different mass flow rate in case of baffle plates has been shown in the fig. 5.3.It has been observed that with the increase in the cell temperature the electrical efficiency has been decreased. The maximum and the minimum values of electrical efficiency has been reported as 2.27 and 1.07 and 2.25 and 0.64 in case of 0.052 kg/sec mass flow and 0.104 kg/sec mass flow rate respectively.

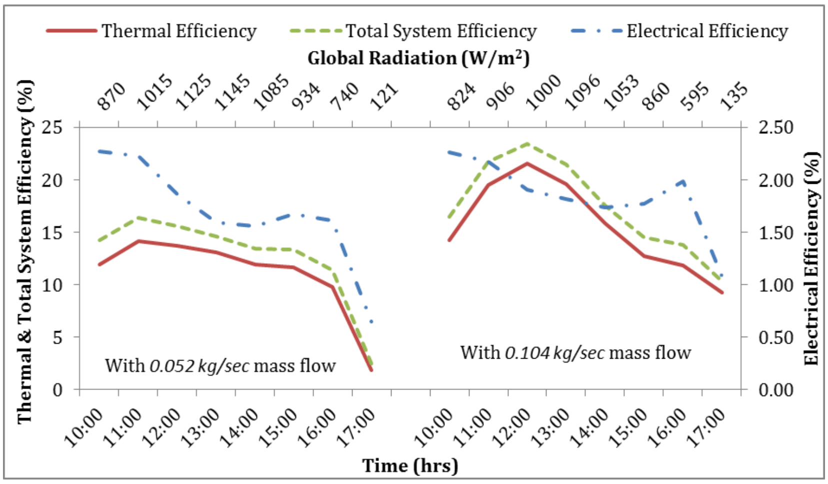
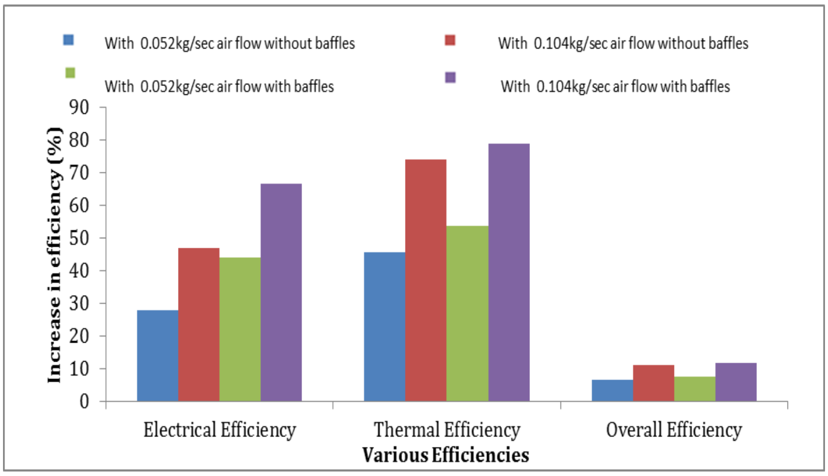


Fig.5.4. Variation of electrical, thermal and overall efficiency of the PV/T system with respect to time and global radiation with baffles

The electrical, thermal and overall efficiency of the PV/T collector with baffles have been plotted against global radiation and time of the day as shown in the Fig.5.4.It has been observed that the electrical efficiency is higher in case of 0.052 kg/sec mass flow till 11:00 hrs due to less cell temperature as compared to 0.104 kg/sec mass flow rate. On the other hand, later on it got higher in case of 0.104 kg/sec mass flow rate. As the mass flow rate is more, thermal efficiency of the PV/T collector is higher in case 0.104 kg/sec, and hence the overall efficiency is higher.



*Electrical efficiency (%), Thermal & overall efficiency (×100%)

Fig.5.5. Comparison of efficiencies with different mass flow rate and configurations

It has been observed from the figures 4.2-4.3 and 5.3-5.4 that the electrical, thermal and overall efficiencies are higher in case of baffles arrangement with 0.104 kg/sec air mass flow rate. Fig.5.5 shows the average percentage increase in electrical, thermal & overall efficiencies with respect to natural convection. The average percentage increase in electrical, thermal and overall efficiencies are 66.56, 7900, 1189 respectively. The PVT hybrid system with low cost heat extraction modification of baffles with 0.104kg/sec air mass flow rate gives the better performance than the without baffles.

5. CONCLUSION

In this study an attempt has been made to show the effect of utilizing baffle plates as a heat transfer medium to achieve better electrical efficiency of PV cells by reducing the absorber/cell temperature. Following conclusion has been drawn from the study:

1. The electrical performance of PV/T solar air collector with and without baffle plates with two different mass flow rates of 0.052kg/sec and 0.104kg/sec has been experimentally obtained. And it is observed that the PVT air collector with baffles with 0.104kg/sec mass flow rate gives as 2.27maximum and 1.07 as minimum electrical efficiency albeit, in case of 0.052 kg/sec mass flow rate it is 2.25 and 0.64.

2. The electrical performance of the PV/T solar air collector without baffle plates with two different mass flow rates of 0.052kg/sec and 0.104kg/sec has been also observed and reported that an average of 16% of electrical efficiency of the PV system can be enhanced by increasing the air mass flow rate from 0.052 kg/sec to 0.104 kg/sec.

3. The effect of baffles and mass flow rate on the cell temperature has been also shown and found that the baffles with higher mass flow rate reduces the significant amount of temperature.

4. Here in this study only two mass flow rates have been compared, as the previous studies revealed that the mass flow rate affects the performance of the system in different ways and the effect of mass flow rate is different for different heat extraction designs modifications like in case of baffles plates 0.104 kg/sec is better than the 0.052kg/sec. Further study can be carried out for the same system with different mass flow rates, And also fthe same monocrystalline PV panel can be used with different heat extraction designs improvement.

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