Comparative Performance Study of Conventional Air Collector and Photovoltaic-Thermal (PV-T) Air Collector

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Abstract: Solar collectors with integrated photovoltaic and thermal system are gaining interest in solar research communities. An attempt is made to study the effect of replacing the top glazing of a conventional air heater with photovoltaic module. For this purpose, a solar air collector is fabricated and tested for different temperature variation in the collector. The collectors were provided with DC fan having 0.22m^3/sec discharge for circulation of air. The module used is mono/multi crystalline of 10W$_p$. The results were plotted for heat collection and different temperature profiles. The results show that heat collected with one glazing is less than with one module. The results also show that the chance of leakage with increasing the number of modules also increases. The highest temperature reached with one glass cover is around 91 ºC. The setup was tested for drying of coriander leaves. As expected the overall performance of the PV-T collector is better than the conventional solar air heater.

Keywords: Solar photovoltaic-thermal collector, air collector, hybrid collector.

1. INTRODUCTION

Solar energy technology acceptance is dependent on various factors such as its efficiency, cost effectiveness, durability, reliability and life cycle, etc. The major application of solar energy can be classified into two categories i.e. 'Solar thermal applications' and 'Solar photovoltaic applications'. There has been advancement in the efficiency of various solar technologies. The efficiencies of solar collectors have been reported around 40 to 60% for low and medium temperature application [1].

The flat plate solar collectors are the most common solar thermal devices that employ a heat transfer fluid flowing over an absorber plate. A flat plate collector comprises of an absorber plate, a transparent cover, a casing and insulation to avoid heat loss. The absorber plate is the main component of the solar collector which is generally made up of CI Sheet or Aluminium and GI sheets. The absorber plate is painted black or selectively coated for maximum absorption. These collectors are preferred up to a temperature less than 100ºC. The figure 1 shows the schematic of flat plate collector.

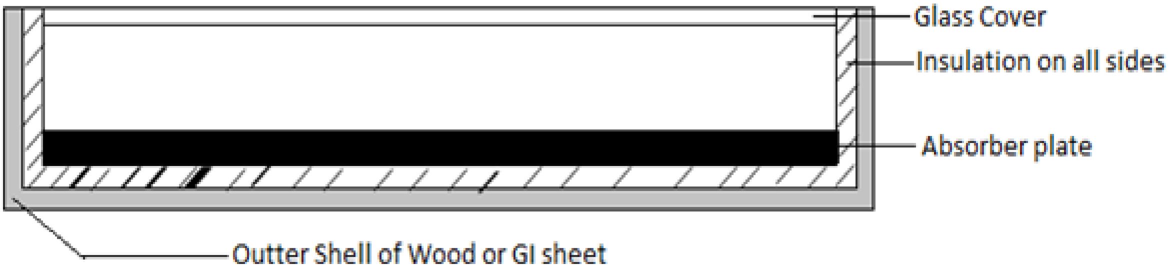

Figure 1: Schematic of Flat Plate Collector

Interest in the direct electric conversion technology i.e. Photovoltaic PV has a significant increase due to falling price, introduction of newer materials and incentives given by government agencies. These technologies are still not gaining commercial success because of low efficiency and cost of production is still higher. The efficiency of photovoltaic cells or modules is measured under controlled conditions (i.e. solar irradiance of 1000 W/m^2, cell temperature 25ºC, etc.). But in actual practice the nominal operating cell temperature (NOCT) is much higher than the reference cell temperature of 25ºC. It is considered that the major reason for reduced efficiency of the cell is due the higher NOCT. To enhance the efficiency of the cell and overall electrical output of the module this heat should be extracted. In order to extract the heat content, a fluid is allowed to pass under/and or over the module.

Many combined Photovoltaic-Thermal Collectors have been proposed, design and tested in recent past for both air heaters as well as water heaters [2,3]. There has also been a study on the effect of fins on the heat transfer rate and efficiency; it reports the considerable reduction in the solar cell/module temperature from 82°C to 66°C [4]. The figure 2 below shows the schematic of finned plate PV/T solar collector used in the study [4].

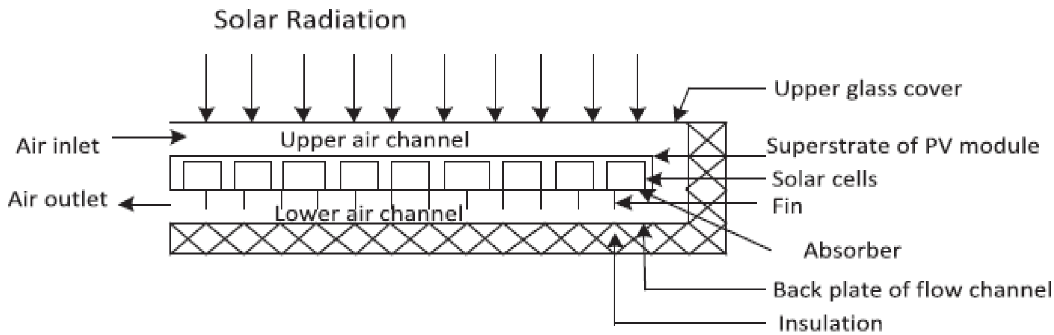

Figure 2: Schematic of finned PV/T collector [4].

In the present study, an experimental model of air collector is designed for a small scale, household activities such as drying the vegetable, herbs etc and air heating which can be used as hair drying, body massage to remove pain and room heating.

2. EXPERIMENTAL SETUP

An experimental model was fabricated to accommodate four different configuration making two conventional air heaters and two Photovoltaic thermal air heaters. The configuration one is termed as one glass, second as one module, third as two glasses and fourth as two modules. The outer case of the solar air heater is 1220 × 355 mm^2. The insulation of thermocol (Styrofoam) of 4 mm thickness is provided on all sides and bottom of the outer case. The absorber plate is divided into two parts of 292 × 343 mm^2. The height of the air duct is kept to 90 mm. The passage is provided with two DC fans of 12 Volts to circulate the air for forced convention. The figure 3 shows the experimental setup in working condition which is installed at rooftop of Mechanical Engineering Department, Motilal Nehru National Institute of Technology (MNNIT) Allahabad, Uttar Pradesh, India.

Figure 3: Experimental setup in working condition.

Figure 4: Label of solar panel.

The setup utilizes 6 copper-constantan thermocouples and a digital temperature indicator to measure the temperatures at various points such as plate temperature, glass temperature, air in temperature, air duct temperature, air out temperature and cabinet temperature. The photovoltaic module used is a Mono-crystalline solar panel TET-1210 by Thrive Energy technologies. The label provided with the open voltage and short circuit current is shown in figure 4.

3. RESULTS AND DISCUSSION

The experiments were performed from April 29, 2014 to May 2, 2014. The results were plotted for the heat collected and for temperature profiles of various configurations. The graph shown in figure 5 is for heat collected per kg of air in different configurations. It is evident that the more heat is collected from one module configuration.

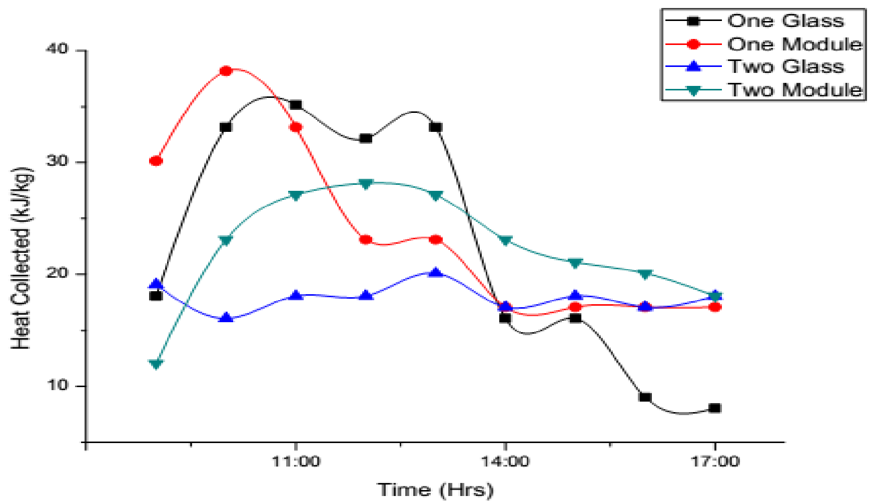

Figure 5: Time v/s Heat collected per kg of air

The figure 6 below shows the temperature profiles of one glass and two glass configuration. It is seen that the maximum temperature achieved by the plate is 91°C. The maximum temperature in two is 81°C.

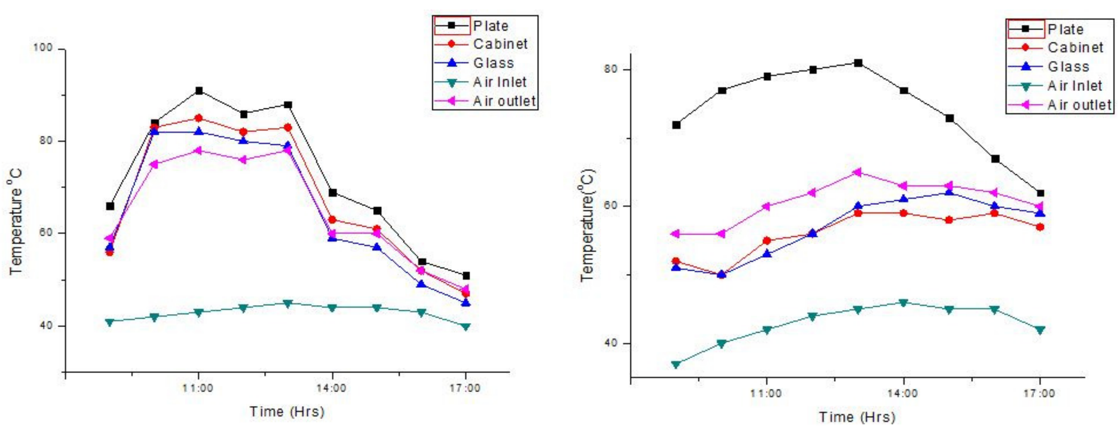

Figure 6: Time v/s Temperature for one glass and two glass

The figure 7 shows the temperature profile of one module and two module configuration.

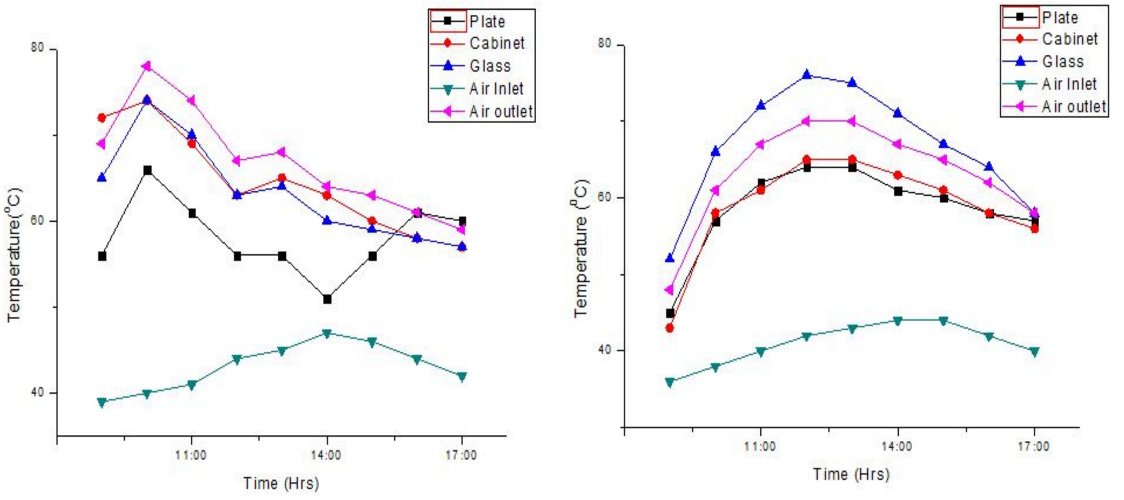

Figure 7: temperature profile of one module and two module configuration

4. CONCLUSION

From the obtained results, it is concluded that the better way to increase the efficiency of the PV module is to keep it in STC (standard testing Condition). This can be achieved by using a Photovoltaic thermal collector (PV-T). In module configuration, plate temperature is not having significant values as the heat is transferred from module to air and thus it can be said that module is a replacement for absorber plate and should be used instead of an absorber plate.

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