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Towards an Improved design of Solar PV/T Collector and Investigation on PV Cell Performance Coupled with Air Cooling System

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Abstract

The quest for sustainable energy and clean environment is now the biggest challenge for both engineers and researchers. Though numerous researches are ongoing, the most available, low-priced and common renewable energy source is the solar energy. The energy comes from in two different forms namely, heat and light. Several technologies have been developed until now to utilize these energies efficiently. Solar collectors such as air heater is the most common and widely used technology that has been used for many purposes like drying and other process works. It collects the energy in the form of heat. On the other hand, Photovoltaic (PV) cells harnesses light energy in the form of electricity. However, the heat energy from the sun plays an adverse effect on the PV cells. From this point of view, a hybrid concept collector comes that is self-sustained, more efficient and compact. In this system a thermal collector together with PV cells is used, so that the heat from the PV cell can be removed and its efficiency can be increased. In this study, a design of a solar PV/T system is proposed where air is used for cooling the PV modules and the effect of temperature on PV cell is investigated.

Keywords: 3-5 keywords, separated by commas. Photovoltaic, Solar collectors, Solar energy

1. Introduction

The available energy sources can be broadly classified in two types: Conventional (nonrenewable) and non-conventional (renewable) [1]. Conventional energy sources are polluting and are leading to global pollution [2]. There is an increasing towards the use non-conventional resources, which are non-polluting and lead to healthier environment. Solar energy is important as an alternative energy source as fossil fuel resources are limited and their use is associated with a number of negative environmental effects such as global climate change and air pollution. Solar energy, which is a non-conventional energy resource, can be converted into thermal energy or directly into electricity. The integrated arrangement for utilizing thermal energy as well as electrical energy, with a photovoltaic module is referred to as the hybrid PVT system. PVT collector produces thermal and electrical energy simultaneously and hence it is referred as hybrid PVT system. A number of researches have been done on the solar Hybrid PV/T air collector using air or water as the working fluid. The cell efficiency decreases with increase in temperature. Also the thermal efficiency of a PV/T dual fluid collector with metal absorber is nearly 80%, and electrical performance of the system is satisfactory and still scope for further improvement of cooling the photovoltaic panels M. Srinivasand, S. Jayarajgive [3]. Typical solar cells have an efficiency of 11-15% [4], using the PV/T technology it can be observed that the electrical efficiency increases. Further using Nano fluid having excellent heat transfer characteristics in the thermal collector the electrical efficiency of the PV panel as well as the thermal efficiency of the solar collector would increase R. Gangadevi, Shobhit Agarwal and Shirsho Roy [5]. The combined PV/T system has been designed where the solar panels are placed above the collector surface. Panel is cooled by air flow above the collector surface which also act as air heating system but a large fraction of collector exposed area is covered by solar panel that have been found as major limitation, Maruful Haque and Md. Sharif Ahsan [6]. After the background study it can be seen that the individual efficiency of a Photo voltaic cell is lower than a solar hybrid system using water or air as coolant. It is also very cost expensive for the individual set up of a solar panel or a solar thermal collector to get electricity, hot water, hot air individually. For these reasons a hybrid PV/T system is installed in this project from which we get electricity, hot water and hot air from only one setup. And it is a cost effective and more energy efficient system than an individual system. In this study, a self-sustained solar air heater has been designed where the electrical power for fan of air heater is provided by the system itself. Moreover, extra energy is stored in a battery pack.

2. Materials and method

In this study, the following assumptions were considered to design the system.

1. Air behaves as an incompressible fluid.
2. The solar panels are fully lighted.
3. All types of possible leakages are prevented, so there is no heat loss

Moreover, a numerical analysis was conducted to find out the efficient dimensions of the solar air heater. From this analysis, the probable temperatures of the solar panel were determined. After getting satisfied data from the simulations, the construction process was conducted. The whole system consists of the following components.

TABLE 1. List of components with specifications

Material	Specification	Material	Specification	Material	Specification
Wooden Box	48 inches× 28 inches× 8 inches	Transparent cover(glass)	48 inch× 28 inches× 2 .5 mm	Charge Controller	1piece
Cork sheet	48 inches× 28 inches× 2 inches	MS sheet	48 inch× 28 inches (1 pieces)	Fan	1 piece
Iron frame	8 Kg	Charge Controller	1piece	Storage Battery	12 V 1 piece
Pudding, screw, wire, etc.	2 packets pudding and small amount of screw and wires	PV cell	30.6 cm× 23.6 cm (4 pieces), 5W	Paint, brush, terpin	0.5-pound paint with terpin and brush

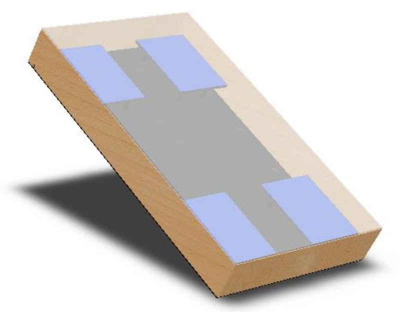

Figure 1. Solar PV/T system

FIGURE 1. displays the system. The system was so designed that the PV modules have its surface exposed to the sun and the air passes over and below of it. This process not only cools the surface of the PV module and increases its efficiency, but also increase the surface area for air heater to extract more heat from it. Moreover, the capacities of the solar panels as well as the battery were determined knowingly. The PV panels charges the battery as well as drives the motor of the fan that is used to blow the air through the system. The effect of temperature on PV panel efficiency was first modeled using MATLAB and then the results were validated by the experimental setup. Moreover, the effect of temperature on battery charging and the dynamic change of state of charge (SoC) during was determined using MATLAB Simulink.

3. Model development and boundary conditions

To analyze the system feasibility and development in design a computational fluid dynamics (CFD) analysis coupled with heat transfer and radiation physics was carried out. To do so, ANSYS FLUENT was used. The used turbulent model was shear-stress transport $k-\omega$. Moreover, from the result of this analysis, a mathematical model was developed in MATLAB Simulink which was used to determine the probable efficiency of the system. The boundary condition for these analyses was the day temperatures and the air mass flow rate produced by the blower. The MATLAB Simulink model was also used to determine the change in SoC of the battery with and without the air cooling of PV cells for a particular amount of time.

4. Results and discussion

Temperature and Efficiency of Air Heater: In this section, the temperature and efficiency of solar air heater is discussed. Due to the increase in surface area, the temperature of the air heater increases. It behaves almost like a double pass air heater due to the presence of PV modules inside the system. FIGURE 2 and FIGURE 3 shows the outlet temperature and efficiency of the system.

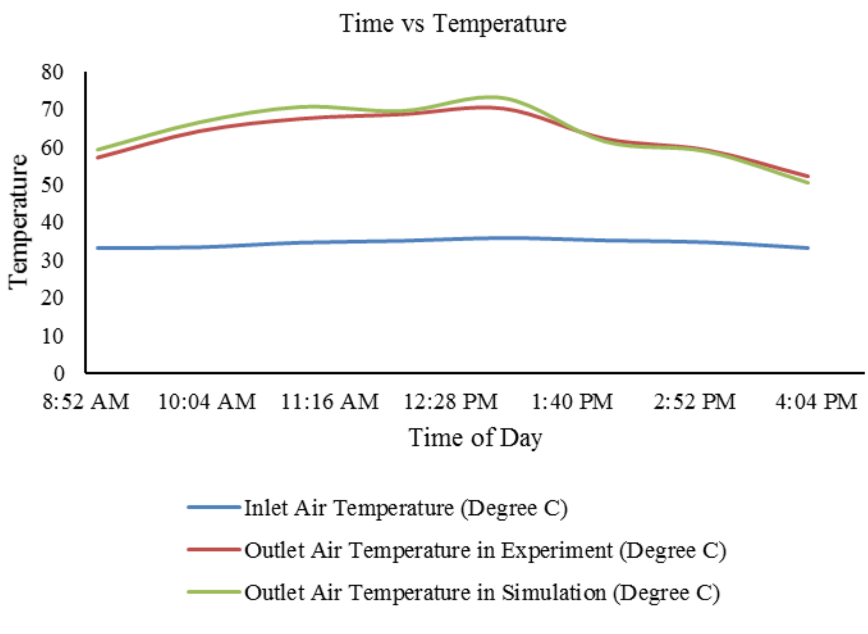

Figure 2. Outlet and inlet temperature of air at various times of the day

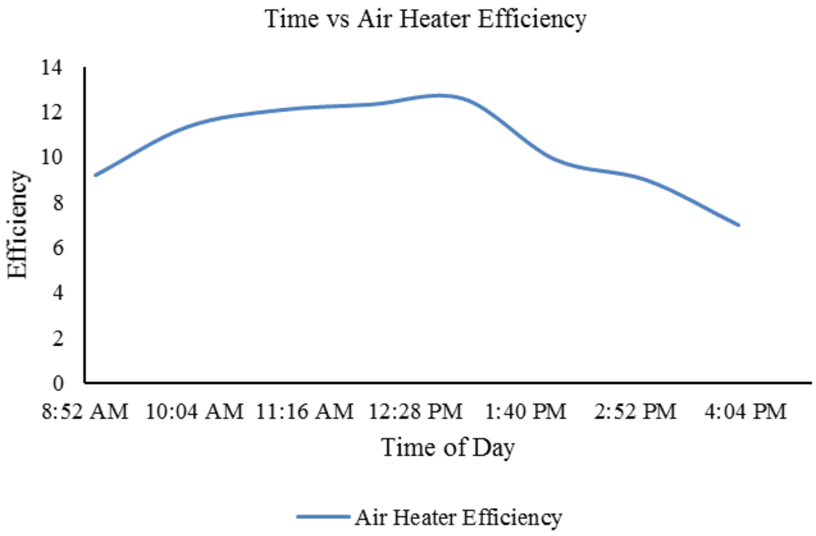

Figure 3. Efficiency of air heater at various times of the day

In Figure 2 we can see the simulated and experimental results of the outlet temperatures are quite equal in magnitude. This confirms the accuracy of the design. Moreover, it also shows an almost constant difference between inlet and outlet temperatures which is considerably high. In FIGURE 3, the efficiency of air heater throughout the day is showed. This suggests that the model will give the maximum efficiency from 12 PM to 1 PM of the day.

PV Panel Temperature and Efficiency: One of the main focuses of this study was to determine the relation between temperature and efficiency of PV solar panel. FIGURE 4 and FIGURE 5 shows those results. In FIGURE 4, the temperature of PV panel with and without the air heater is shown. This shows a considerable amount of temperature raise in PV panel without the air heater throughout the day.

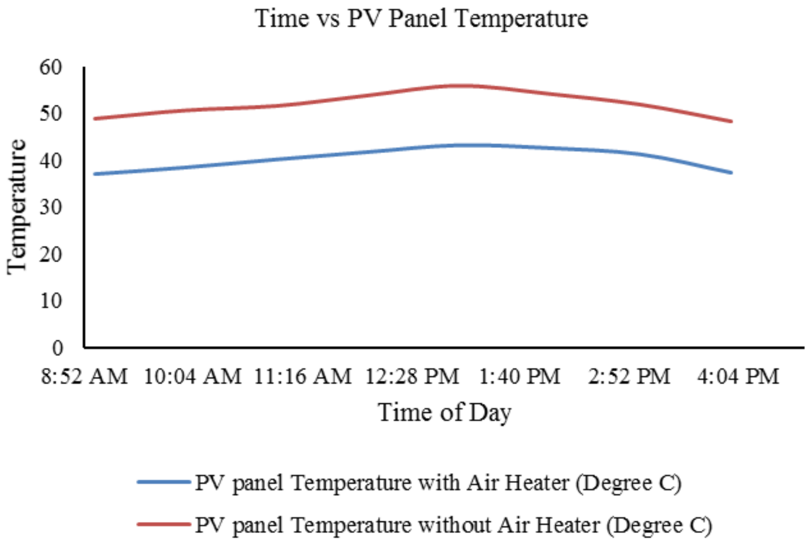

Figure 4. PV panel temperature with and without air heater

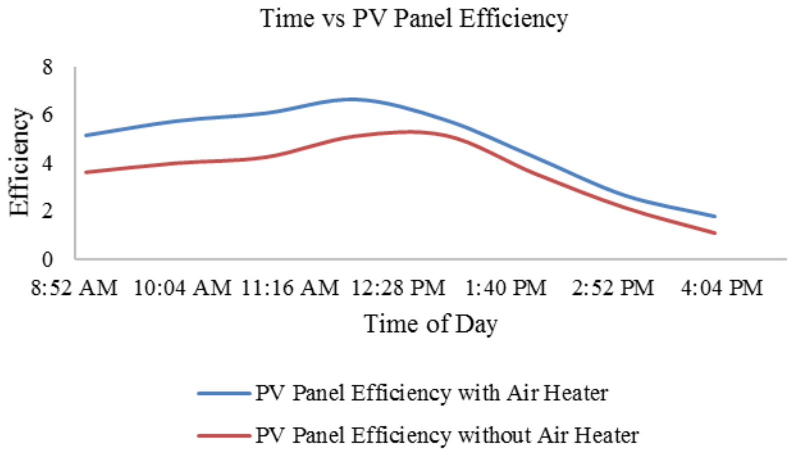

Figure 5. Efficiency of PV panel with and without air heater

Figure 5 shows the difference between the efficiencies of solar PV panels with and without air heater. The result is quite predictable. It shows an increased efficiency of the PV panel with the coupled air heater. The heat removed by the air heater from the panel is the main reason behind this increased efficiency.

Relation between Battery Charging and PV Panel Temperature: In previous results and discussion, it was clear that, the efficiency of the PV cell increases with cooling. To do so, air heater is coupled in this studied system. However, the relation between the battery charging and solar PV cell temperature has not yet been discussed. The relation was determined, as mentioned earlier by using MATLAB Simulink at various times of the day based on the experimental data. FIGURE 6 shows the relation in the form of change in state of charge (SoC) in one hour with temperature.

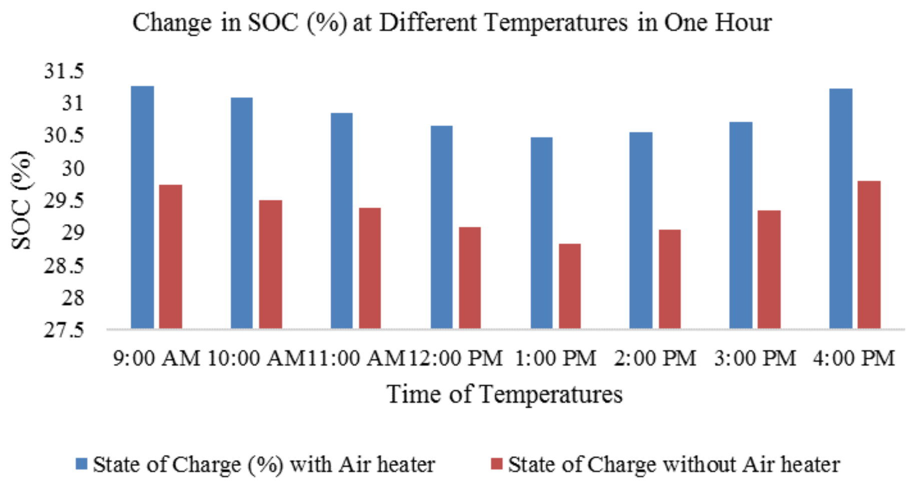

Figure 6. Relation between charging of battery and PV cell temperature

It is quite clear that with the air heater coupled system, the battery will be charged much faster than that of single used PV cell charging system.

5. Conclusion

Solar PV/T hybrid system is quite helpful for solving energy crises. Moreover, its compact and increases its own efficiency by applying simple physics. The system studied here is not only self-sustained but also can deliver extra power to the external source. The system can be made more efficient by increasing the heat transfer rate of air and integrating water cooling of the solar PV panels. However, the system should be further developed for commercial and everyday’s uses.

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