Available online at www.sciencedirect.com

ScienceDirect

Procedia Technology 24 (2016) 513 – 522

Procedia Technology

International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015)

Numerical Simulation for Solar Hybrid Photovoltaic Thermal Air Collector

Lippin pauly[a]*, L Rekha[b], Christy V Vazhappilly[a], Melvinraj C R[a]

[a]*Department of Mechanical Engineering, Jyothi Engineering College, Jyothi hills Thrissur 679531, India*
[b]*Department of Mechanical Engineering, Government Engineering College, Thrissur 680009, India*

Abstract

Solar energy is one of the renewable energy sources which have potential for future energy applications. The current well-liked technology converts solar energy into electricity and heat individually. In this paper, an effort is made to simulate and evaluate the overall performance of a hybrid photovoltaic thermal (PV/T) air collector using computational fluid dynamics (CFD) software. The numerical analysis of the flow and heat transfer in hybrid PV/T systems is computationally quite complicated and the number of research works on this topic is quite low. Based on numerical analysis, the performance of a solar hybrid PV/T air collector has been studied. The numerical simulation was done in commercial software ANSYS FLUENT 14.5.0. The electrical energy conversion in solar cell was calculated with user defined function. The numerical results are validated with experimental results from literature. The results show a good agreement between experimental and simulated result for outlet air temperature and PV cell temperature. Using validated model, effect of mass flow rate and duct depth on the performance of solar hybrid PV/T collector has been studied and optimum values are identified. In order to increase the overall performance of a solar hybrid PV/T air collector, a novel design is proposed here. The result shows in the proposed design gives 20% enhancement in overall performance compared to conventional solar hybrid PV/T air collector.

Peer-review under responsibility of the organizing committee of ICETEST – 2015

Keywords: PV/T air collector; solar radiation; CFD simulation.

.

* Lippin Pauly. Tel.: +919447054926.
E-mail address: lippinpauly@jecc.ac.in

Peer-review under responsibility of the organizing committee of ICETEST – 2015
doi:10.1016/j.protcy.2016.05.088

1. Introduction

Over the past century fossil fuels have been provided most of our energy requirements because these are much cheaper and more convenient than energy from other sources, and until recently environmental pollution has been of slight concern. With the increasing demand of energy, nowadays the world daily oil burning up is 85 million barrels of crude oil. In spite of the well-known consequences of fossil fuel combustion on the ecosystem, this is estimated to increase to 123million barrels per day by the year 2025[1]. This is the main cause for pollution. Many researches towards the solar energy arise all over the world due to the anxiety of this reason. The utmost advantage of solar energy as compared with other forms of energy that is ecological friendly and plentifully available and can be supplied without any ecological pollution. Usually, devices intended for using solar energy fall into two major classes depending on the process of its conversion: either heat or electricity, like thermal collectors and photovoltaic modules correspondingly. Solar thermal energy collectors are particular kind of heat exchangers that convert solar radiation into thermal energy usually through a moving fluid. Photovoltaic (PV) is the most convenient way of utilizing solar energy by directly converting it into electricity. Among these, one that has developed very enormously is the photovoltaic (PV) technology. A photovoltaic system consists of solar cells and auxiliary components. It converts the solar radiation directly into electrical energy. The temperature of PV modules is increased by the absorbed solar radiation that is not converted into electrical energy, causing a decline in their efficiency. For monocrystalline (c-Si) and polycrystalline (pc-Si) silicon solar cells, the efficiency decreases by about 0.45% for each degree rise in temperature. For amorphous silicon (a-Si) cells, the effect is fewer, with a decrease of about 0.25% per degree rise in temperature depending on the module design [2]. So due to the disadvantage of more energy payback period & poor efficiency at high temperatures of a photovoltaic (PV) module, the cost of electricity produced by a PV module is higher than that of electricity produced by fossil fuels. In order to reduce such demerits, a PV module can be incorporated with cooling systems by using ducts or channels under the PV module. So it can also be used for thermal applications such as air/water heating, space heating, solar agricultural drying and can then be more cost effective. Such systems are referred to as hybrid photovoltaic thermal systems. A photovoltaic-thermal hybrid system (PV/T) produces both electricity and heat by means of one incorporated component, in which cells are applied on the thermal absorber.

It was not long before scientists noticed that the PV panels which they used to convert the incident solar irradiation to electricity were able to convert only a relatively small fraction of the irradiation to electricity, while a major portion of the solar energy would convert into heat. Moreover, heat affects the efficiency of PV cells adversely, decreasing their energy generation potential [2]. Thus, scientists began exploring means for decreasing the temperature of PV panels in order to enhance their conversion efficiency. Evans [3] was amongst the first to investigate the possibility of harnessing the heat generated on PV panels as utilizable thermal energy. However, research on the field has been very slow, with studies necessary for the design of a commercial PV/T system taking place primarily during the past decade. Methods to evaluate and optimize the efficiency and performance of PV/T systems have been recommended in most studies, with a few studies investigating their performance with numerical simulations.

Garg and Adhikari [4] have developed a steady state model in order to predict the overall performance of PV/T air heating system with single and double glass configurations. Working with a steady state PV/T model, they pointed out that further than the critical point the single glass cover collects more heat than double glass. They conclude that the parametric studies of PV/T air collector show the effect of collector length, collector area, mass flow rate and duct depth on the overall efficiency of PV/T collector.

Dubey et al [5] carried out an analysis on different configurations of glass-to-glass and glass-to-tedlar PV modules and developed an expression for electrical efficiency as a function of climatic conditions and design parameters. The result shows that glass-to-glass PV module incorporated with air cooling duct have the maximum efficiency and its annual average efficiency is about 10.41%.

By use of validated theoretical and experimental models, Tiwari et al [6] proved the degree of improvement by integrating unglazed PV module with duct air cooling for meteorological conditions of Indian climate. The result also explored to found out an optimal values for mass flow rate of air, duct depth and duct length

Joshi et al [7] have analysed and compared the overall performance of hybrid PV/T air collector with glass-to-tedlar and glass-to-glass configurations. The results showed that the hybrid PV/T air collector with glass to glass configuration has better results than glass to tedlar configurations. The results also explored to found out the effects of different control parameters such as mass flow rate and length of the duct and it showed the parameters have