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Computational Analysis of Performance of Solar Photovoltaic Thermal System

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Abstract—In this paper, an effort is made to simulate and evaluate the overall performance of a hybrid photovoltaic thermal (PVT) panel using computational fluid dynamics (CFD) software. The numerical analysis of the flow and heat transfer in hybrid PVT 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 PVT system has been studied. The numerical simulation is done in commercial software ANSYS FLUENT 16.0.The results show that with cooling of the bottom panel (tedlar) there is an effective increase in the overall efficiency.

Keywords—***computational fluid dynamics,hybrid photovoltaic thermal,heat transfer,overall efficiency.***

I. Introduction

Renewable energies including solar energy, wind power, hydropower, bio fuel, geothermal energy are suggested to provide a solution to resolve the global warming problem and alleviate the potential of energy crisis. The demand of fossil fuels will be reduced when the renewable energies become popular in the energy market. Furthermore, potential climate change will be mitigated when the renewable energies replace fossil fuels in the future.Solar energy is one of the most promising energy sources which have potential for future energy applications. Efficient utilisation of renewable energy resources,especially solar energy, is increasingly being consideredas a promising solution to global warming and a means of achievinga sustainable development for human beings.

Photovoltaic is the technical term for solar electric. Photo means “light” and voltaic means “electric”. The Photovoltaic cell is made of semiconductor materials usually silicon and used to convert sunlight into direct-current electricity. When light with wavelengths less than 1100nm strikes a PV crystalline cell, electron hole pairs are created in the cell, the electric field sends the electrons from p-type to n-type silicon and the holes from n-type to p-type. Disruption of electrical neutrality occurs during the photovoltaic effect. An external load is needed to restore the equilibrium. The external load will provide a current path which allows electrons to flow from n-type to p-type silicon; electron recombines with the hole when it reaches the p-type silicon.

II. COMPUTATIONALANALYSISPROCEDURE

Solar PVT panel consists of 5 layers of varying thickness. The thermal conductivity of each layer varies. Of these cell layer has more thermal conductivity. The safe temperature of the polycrystalline cell is 40°C. The model is designed in SOLID WORKS software,a duct is designed and it is assembled with PVT panel. The entire design is imported in CFD for temperature distribution analysis. In order to analyse the temperature distribution on the surface of the panel, initially an irradiation (G) of 800 W/m^2 is given.

Table 1.Properties of layers of PVT

Material	Thermal conductivity (W/m.K)	Specific Heat Capacity (J/kg.K)	Density (kg/m^3)
Top Glass	2	500	2450
EVA	0.311	2090	950
PV Cell	130	677	2330
Tedlar	0.15	1250	1200

The air flow velocity is given at the varying rate. Air is made to flow under the panel to carry away the heat transmitted by the sun.

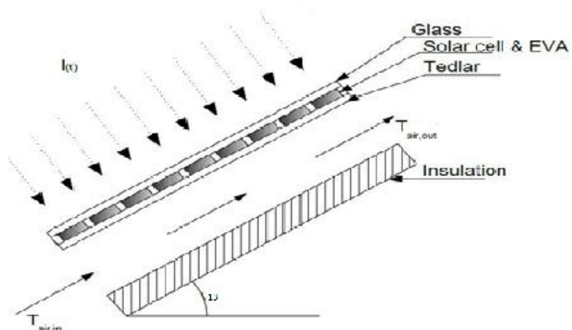

Figure 1.Cross sectional view for PV/T air system

The depth of the duct plays a vital role in improving the overall efficiency because if the duct depth is too small there will be an increase in pressure drop or if the duct depth is too large there will be a decrease in air contact with the tedlar.

The figure 3 shows the prototype of the solar PVT panel with the air duct. The panel has to be inclined at 13^{o}in order to track solar radiation at different timing.

Table 2. Mechanical specifications of Solar panel

The inclination varies based on the latitude and longitude of the place. The panel has to be mounted in place where shade of other objects like buildings, water tank and trees should not fall on it. This is because shading affects the efficiency of the solar panel.

Air duct is assumed to be designed in wood. The reason for designing in wood is it will have least thermal conductivity and does not absorb atmospheric heat. While analysing air and the duct are made as a single body for simplification. The air flow rate is varied from 1 to 10 m/s to find the optimum flow rate. The variation is studied and compared to find the average air velocity to be made flow through the duct in solar panel.

Name	Value
Module Dimensions	1500 x 660 x 34±2 mm
Frame	Anodized Aluminium
Front Material	Tempered Glass 3mm
Type of Cells	Polycrystalline
No. of Cells	36
Weight	9.75 kg

Computational fluid dynamics is a set of numerical techniques and algorithms to evaluate and analyze the problems related to fluid flow and heat transfer. In this study, the CFD simulation of solar photovoltaic thermal system is analyzed by using ANSYS Fluent tool under transient conditions. The sequential technique performed in thermal simulation of solar PV/T system are geometric modelling, grid generation, and boundary conditions setup and solution results.

The three-dimensional computational domain of solar PV/T system was modelled using ANSYS geometric modelling tool. Computational domain of photovoltaic thermal system used in the numerical simulation are used based on the above given details.

The grid generation is performed by using ANSYS ICEM CFD. The good quality mesh is achieved by employing hexahedral elements of fine size and patch conforming technique. The number of nodes and elements are found to be 752136 and 712800 respectively.

Appropriate boundary conditions were impressed on the computational domain, as per the physics of the problem. Inlet boundary condition was specified as velocity inlet condition. Outflow boundary condition was applied at the outlet. Wall boundary conditions were used to bound fluid and solid regions. In viscous flow models, at the wall, velocity components were set to zero in accordance with the no-slip and impermeability conditions that exist there. A solar insolation is applied at the top surface of the glass. The bottom and side surfaces of the solar PV/T system are defined as wall with zero heat flux condition to effect insulated conditions. The time step and number of time steps used in the simulation study is 600 seconds and 54 respectively.

III. RESULTS AND DISCUSSION

Parametric study is carried out in order to study the effect of different operating and design parameters on performance of the hybrid PV/T system. The variations of different parameters were taken into account for numerical analysis.

By analysing various results, it is understood that the air flow velocity is optimised at 3 m/s. The CFD simulated results that at this cooling rate there is an increase in efficiency

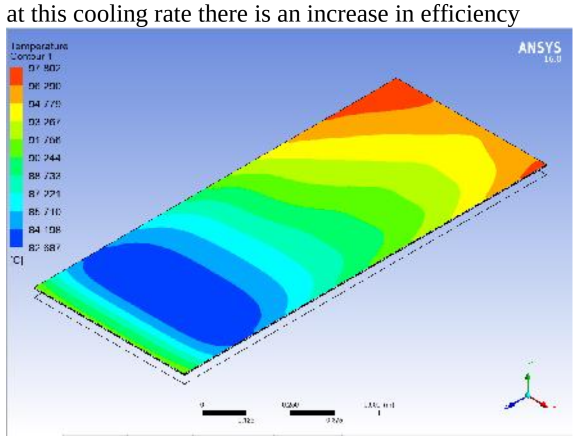

Figure 2.Temperature Contour of Solar Panel in ANSYS

The above figure shows the complete temperature distribution of the panel when air at the velocity of 3m/s is made to flow through the duct. The ultimate aim is to decrease and maintain the tedlar temperature. On implementing, there will be an efficient cooling with this airflow.

In the present work, the effect of mass flow rate with respect to overall efficiency of hybrid PVT air collector keeping the other parameters constant is studied.

IV. CONCLUSION

In this project, the performance evaluation of a hybrid PVT air collector was carried out. Electrical conversion inside the

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panel was compensated by user defined functions to increase the calculation precision of PVT air collector thermal parameters. Finally, validation, numerical simulation and parametric studies were carried out and based on the studies a new duct design is proposed. The numerical simulation results of this study are in good agreement with the experimental measurements noted in the previous literature. With increase in mass flow rate, the overall efficiency also increases initially due to the fact that more air passes through the duct extracts more thermal energy and reaches to an approximate constant nature at higher flow rates due to less flow residence time inside the duct.

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