Modeling a Combined Photovoltaic-Thermal Panel

Ernesto Gutierrez-Miravete[1], Bradley Fontenault[2]

[1]Rensselaer Polytechnic Institute, Hartford, CT, USA
[2]General Dynamics-Electric Boat, Groton, CT, USA

Abstract

A novel combined photovoltaic-thermal panel can simultaneously increase the conversion efficiency of the PV cell and utilize some of the excess thermal energy created by the conversion process. The concept is simple and it is shown schematically in Figure 1. Immediately underneath and firmly attached to the PV cell there is a thin-walled aluminum reservoir through which water flows. As solar irradiance is converted into electrical energy in the PV cell, unwanted excess thermal energy is generated due to the intrinsic conversion efficiency limitation of the cell. The excess thermal energy produces an increase in temperature and this in turn reduces the conversion efficiency of the cell. By making cold water flow though the thermal panel underneath the cell, some of this excess thermal energy can be collected and applied to some useful purpose. Moreover, since the cell now operates at lower temperature, its conversion efficiency increases. The net result is an enhancement of the combined photovoltaic-thermal efficiency of the system. A conceptual design for a photovoltaic thermal (PV/T) solar panel has been developed and analyzed to control the inherent temperature increase of PV cells to increase electrical efficiency, while also carrying the absorbed heat away from the panels for a myriad of applications. The Conjugate Heat Transfer physics in COMSOL was used to create a two-dimensional, steady state model of such a combined photovoltaic cell-thermal panel. Figure 2 shows a magnified view of the finite element mesh near the inlet side of the combined panel. Following [1-3], suitable values of solar irradiance, material properties, and boundary conditions were used as initial parameter values for the modeling. Key model results include the efficiency of conversion of the cell and the amount of excess thermal energy recovered by the panel. Variations in the initial values of the input parameters were then introduced to investigate the sensitivity of the computed results. Figure 3 shows the effect of inlet water flow rate and channel dimensions on the calculated temperature of the PV cell. As expected, the cold water effectively removes excess heat from the cell reduces its temperature and increases its conversion efficiency. Figure 4 shows the computed combined PV-Thermal efficiency of the panel as a function of the same input parameters. The efficiency enhancement effect is clear. A conceptual photovoltaic thermal panel design was modeled and analyzed using a commercial finite element software package, COMSOL Multiphysics. The PV/T panel evaluated consisted of monocrystalline silicon PV cells that were bound with a silicone thermal paste to an aluminum reservoir through which coolant water flowed. Numerous simulations were completed to model the heat transfer across the PV/T panel and ultimately to determine the PV/T electrical output and thermal efficiencies of the panel. The highest total PV/T panel efficiencies were achieved for test cases involving combinations of high flow velocity and large flow channel thicknesses. However, the PV/T system with the highest efficiency is most likely not the most desirable configuration for

practical use since while high inlet velocities result in the lowest PV/T surface temperatures, the temperature rise of the coolant water is very small. A cost savings study would be required to determine the optimal balance between electrical conversion efficiency and thermal efficiency.

Reference

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2. H.G. Teo, P.S. Lee, and M.N.A. Hawlader, An active cooling system for photovoltaic modules, Applied Energy 90 (2012) 309-315.
3. H. Chen, Saffa B. Riffat, Yu Fu, Experimental study on a hybrid photovoltaic/heat pump system, Applied Thermal Engineering 31 (2011) 4132-4138.

Figures used in the abstract

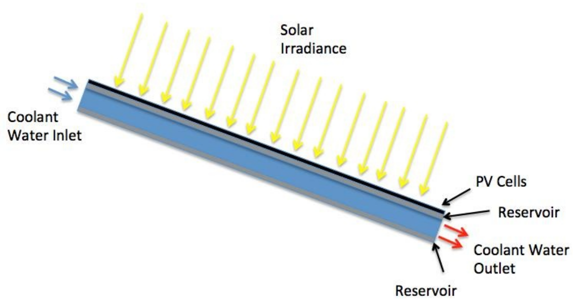

Figure 1: Schematic representation of the combined PV-Thermal Panel.

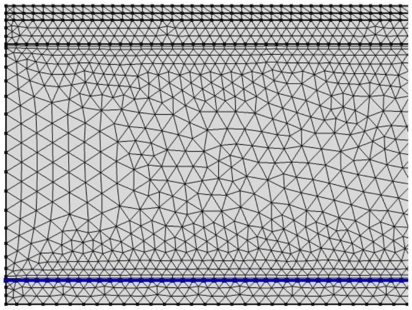

Figure 2: Finite Element mesh detail.

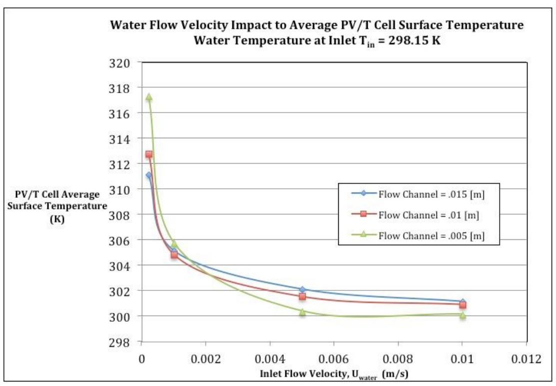

Figure 3: Effect of flow velocity and channel gap on cell temperature.

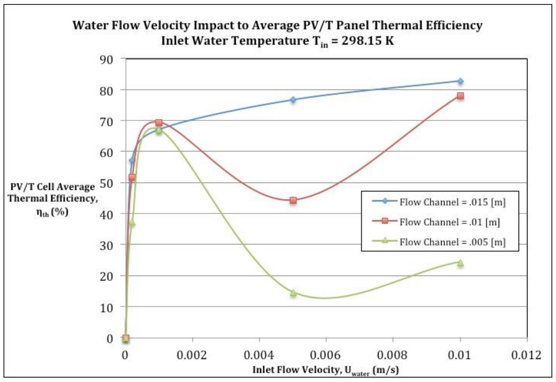

Figure 4: Effect of flow velocity and channel gap on overall efficiency.