Heat Transfer and Working Temperature Field of a Photovoltaic Panel Under Realistic Environmental Conditions

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Abstract

The aim of this work is the numerical study, by finite element analysis using COMSOL Multiphysics®, of the heat transfer and working temperature field of a photovoltaic panel under realistic wind and irradiation conditions. It is well-known that a great portion of the solar radiation absorbed by a photovoltaic module (typically 85% of the incident radiation) is not converted into electrical energy, but it is wasted by the increase of the module's temperature, reducing its efficiency by heat transfer with the surrounding medium [1-2]. The working temperature of photovoltaic modules depends on different environmental factors as the ambient temperature, the solar irradiation, the relative humidity, the direction and speed of the wind; and physical factors as the construction materials and particular installation of the module.

For comparison, we have made a measurement campaign with a standard PV panel (mono-crystalline Si) that has six temperature sensors Pt100 attached. The different irradiation and other environmental conditions have been recorded by pyrometers and a meteorological station.

Use of COMSOL Multiphysics®:

a. Geometry
The geometry of the system contains the following parts:

Solids (domains and shells):
- The aluminium frame of the PV panel.
- The glass of the cover. Thickness: 3 mm.
- The Silicon cells. Thickness: 0.4 mm.
- The EVA (etilene-vinil-acetate) film. Thickness: 0.8 mm.
- The Tedlar back film. Thickness: 0.05 mm. White reflective color.

Gaseous domain:
- The air that surrounds the PV panel.

b. Thermal equations
Gaseous Subdomain: Heat conduction and convection. The velocity field is calculated and

coupled using Navier-Stokes equations. The density and thermal conductivity of air are functions of the local temperature.

Solid Subdomains: Only heat conduction, where the heat generation Q is zero for the Tedlar, glass and EVA parts, and has a non-zero value in the silicon cells, which corresponds to an incident irradiation of 1000 W/m2 homogeneously distributed minus a 15 % efficiency of electrical conversion [1]. The thermal conductivities of the glass, EVA, silicon and Tedlar are 1.7 W/(m·K), 0.23498 W/(m·K), 148 W/(m·K) y 0.1583 W/(m·K), respectively. The specific heat capacity at constant pressure of the glass, EVA, silicon and Tedlar are 780.33 J/(kg·K), 3135 J/(kg·K), 710.08 J/(kg·K) y 1090 J/(kg·K), respectively.

c. Fluid equations
The Navier-Stokes fluid equations are only applicable in the gaseous subdomain (air). The air viscosity is a function of the temperature. The body force acting on the fluid is the buoyancy force due to the dependence of the density of the air with the temperature.

We are making time-dependent calculations during a complete day, including the measured irradiation and wind data as input environmental conditions. From the comparison of the calculated temperature field and the experimental temperature values found in different points of the panel, we will able to assess the agreement of the actual working temperatures against those predicted by the manufacturer in standard conditions [3].

Reference

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3. K. Emery, Measurement and Characterization of Solar Cells and Modules, in Handbook of Photovoltaic Science and Technology, A. Luque y S. Hegedus, eds., (2003).