Energy efficient double-pass photovoltaic/thermal air systems using a computational fluid dynamics multi-objective optimisation framework

Photovoltaic systems have undergone substantial growth for the past twenty years and more than 75% of the solar irradiance is absorbed, but only a small amount of the captured solar energy is transformed into electricity (e.g. ~7−24%). The remaining energy can cause overheating and damage to adhesive seals, delamination and non-homogeneous temperatures. In this paper, a three-step strategy is presented for the development of an energy efficient hybrid photovoltaic/thermal air system by the combination of experimentally validated computation fluid dynamics and optimal Latin hypercubes design of experiments. The combined thermo-hydraulic and electrical performances of five air flow configurations are examined after the selection of several design parameters. The parametric study reveals that the most promising configuration is co-current air flow through two channels above and below the photovoltaic cell. A multi-objective design optimisation process is undertaken for this configuration, where the system is represented by three design variables: the collector, the depths of the lower air flow and the upper air flow channels. A 50-point design of experiments is constructed within the design variables space using a permutation genetic algorithm. The multi-objective design optimisation methodology entails an accurate surrogate modelling to create Pareto curves which demonstrate clearly the compromises that may be taken between fan fluid and electric powers, and between the electric and thermal efficiencies. The design optimisation demonstrates how the design variables affect each of the four system performance parameters. The thermal and electric efficiencies are improved from 44.5% to 50.1% and from 10.0% to 10.5%, respectively.