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Field study of various air based photovoltaic/thermal hybrid solar collectors

Karima E. Amori*, Mustafa Adil Abd-AlRaheem

Univ. of Baghdad, Mech. Eng. Dept., Baghdad, Iraq

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ABSTRACT

In the present work a comparative study for thermal and electrical performance of different hybrid photovoltaic/thermal collectors designs for Iraq climate conditions have been carried out. Four different types of air based hybrid PV/T collectors have been manufactured and tested. Three collectors consist of four main parts namely, channel duct, glass cover, axial fan to circulate air and two PV panels in parallel connection. The measured parameters are, the temperature of the upper and the lower surfaces of the PV panels, air temperature along the collector, air flow rate, pressure drop, power produced by solar cell, and climate conditions such as wind speed, solar radiation and ambient temperature. The thermal and hydraulic performances of PV/T collector model IV have been analyzed theoretically based on energy balance. A Matlab computer program has been developed to solve the proposed mathematical model.

The obtained results show that the combined efficiency of collector model III (double duct, single pass) is higher than that of model II (single duct double pass) and model IV (single duct single pass). Model IV has the better electrical efficiency. The pressure drop of model III is lower than that of models II and IV. The root mean square of percentage deviations for PV outlet temperature, and thermal efficiency of model IV are found to be 3.22%, and 18.04% respectively. The calculated linear coefficients of correlation (r) are 0.977, 0.965 respectively.

1. Introduction

Photovoltaic thermal hybrid solar collectors (hybrid PV/T) systems are systems that convert solar energy into thermal and electrical energy. These systems combine a photovoltaic cell with a solar thermal collector i.e. converts electromagnetic radiation into electricity, and heats a flowing fluid from the absorbed energy. A PV module converts 6–20% of the incident solar radiation into electricity according to its type and climate conditions. Most of incident solar radiation is converted into heat which increases the temperature of Photovoltaic module and reduces its efficiency.

The experimental studies reported on the photovoltaic-thermal (PV/T) system are back dated to, Kern and Russell (1978) [1], who presented the concept of PV/T collector for the first time. Water or air have been used as a fluid for removing the absorbed energy. It has been found that solar irradiation with the wavelength from 0.6 to 0.7 μm is absorbed by the PV cells and converted into electricity, while the remaining irradiation is mostly transformed in form of thermal energy. Raghuraman (1981) [2] developed two different one-dimensional models for the prediction of the thermal and electrical performance of both liquid and air flat plate (photovoltaic/thermal) collectors. Garg and Adhikari (1997) [3] analyzed a PV/T air heating system of a single and double glass covers. Sopian et al. (2000) [4] developed a mathematical model based on energy balance principle. A double pass photovoltaic thermal solar collector suitable for solar drying applications has been tested. A good agreement between the experimental and theoretical results has been obtained. Chow et al. (2003) [5] investigated the BIPVT options of a hotel building in South China at (22.2° N). The PV/T facade was attached to a full day air conditioned services room to investigate its cooling by means of natural flow of air behind the PV models. The effectiveness of PV cooling by natural convection has been investigated. It has been found that both the climate condition and system operating mode affect significantly the PV productivity. Othman et al. (2005) [6] studied theoretically and experimentally the PV/T solar air collector with concentrating reflectors. Shahsavar et al. (2010) [7] designed, built and tested a PV/T air collector with and without glass cover at Kerman, Iran under natural and forced convection using two, four and eight fans. Good agreement between theoretical and measured values

* Corresponding author.
E-mail address: drkarimaa@yahoo.com (K.E. Amori).

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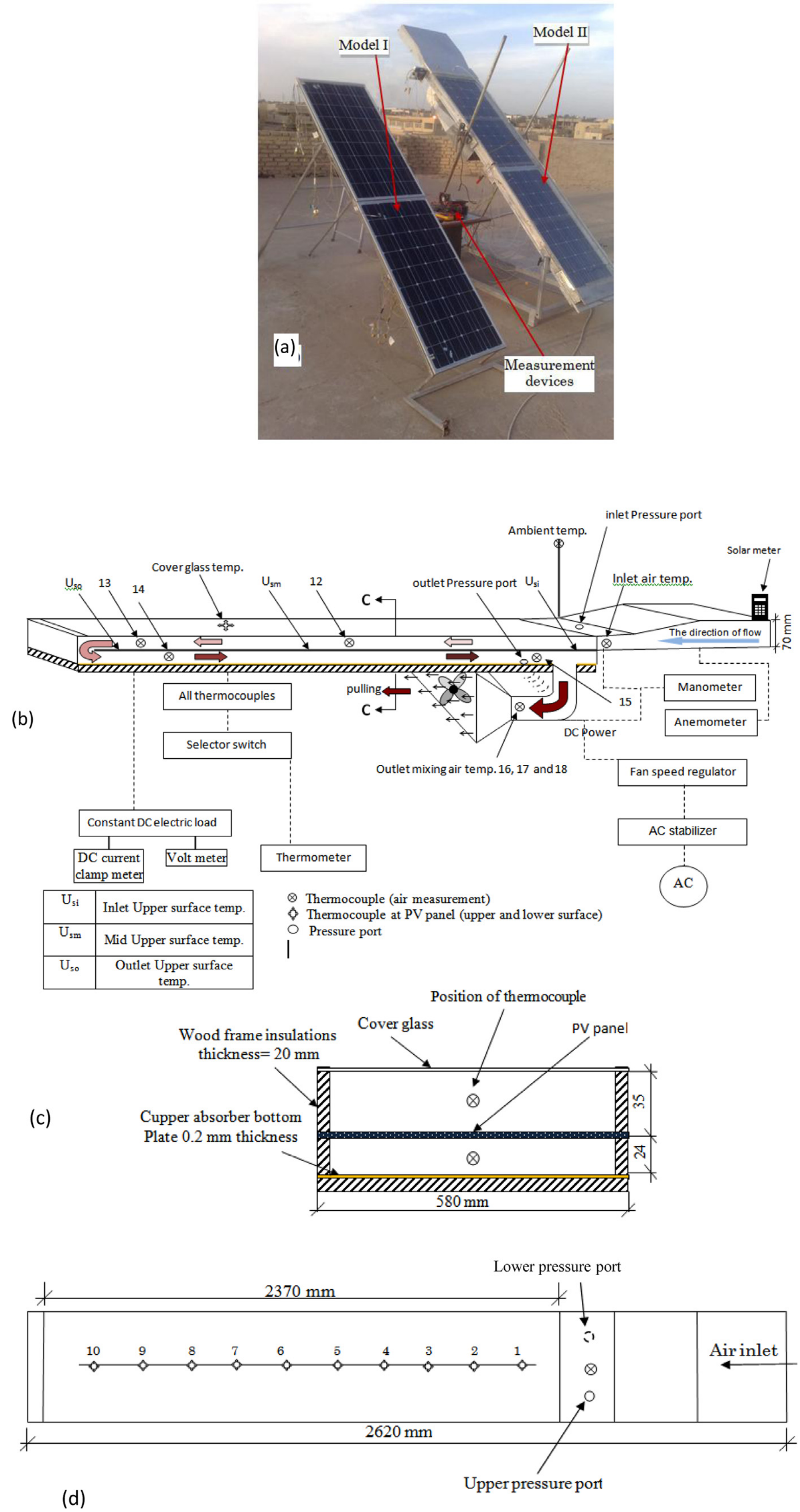

Fig. 1. (a) Outdoor test of model I and model II; (b) Schematic diagram of model II; (c) Cross section view of C–C; (d) Top view of PV panels model II.