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Cooling of a photovoltaic module with temperature controlled solar collector

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ABSTRACT

The efficiency of photovoltaic modules decreases with heating, so there has been an increase with regard to the solution of the problem. Photovoltaic module converts the incoming solar radiation into heat and electric energy. Due to this heating feature of photovoltaic modules, it is likely to produce heat energy from PV modules as well. Such systems are called as both a photovoltaic and thermal systems in the literature. A lot of experimental studies were done by special processing on the PV module. Since the studies require special processing on the module, they remain as laboratory work only. In this study, different PV/T systems were experimentally analyzed for the cooling photovoltaic modules. A simple pipe was placed on PV module as a spiral heat exchanger in order to provide active cooling. Also, the system can easily be applied to large-scale systems. As a result of experimental research, the module efficiencies with cooling were calculated as 13%, and the module efficiencies without cooling were about 10%. As the set temperature increased, module temperature can be increased or decreased. The module temperature was changed according to solar radiation and set temperature. As the solar radiation increased the module temperature decreased in this experimental system. The solar radiation has nothing to do with set temperature for this system.

1. Introduction

It is likely to examine solar energy electricity production systems in two groups: stand alone systems (off grid) and on grid systems. The stand alone systems have to be used at the places where there is no grid system. Their cost is comparatively higher since more battery and panel surface area are added. The stand alone systems are also used in very large areas such as shipping sector, agriculture, aviation, transmitters, satellite systems, and motorway lighting in the absence of grid systems. The solar panels used in these systems can be categorized into three groups. These are polycrystalline solar panels, monocrystalline solar panels and amorphous crystal solar panels. Since the production of polycrystalline solar panels commercially is relatively easier, they are the most preferred panels. In addition, they are much cheaper. The efficiency of these three types of solar panels varies from 10% to 20%. Even though polycrystalline solar panels vary in different sources, their efficiency is 15% at the laboratory. The efficiency in application could be reduced up to 10%. The biggest loss at solar panels occurs in heating, since it could convert 50% of the solar radiation reflect on it into thermal energy. So it makes solar panels possible to be used in the production of thermal energy. The solar panels that were tested at 25 °C panel temperature could be increased up to 70 °C in practice. In order to obtain the efficiency at testing conditions, it is necessary to cool the panels. So as to cool the solar panels and obtain beneficial heat at the same time, such fluids as air, water and so on are used. Therefore, these systems are also called as photovoltaic and thermal systems. There have been a great many studies in the literature carried out into obtaining both heat and electricity out of solar panels.

Mishra and Tiwari analyzed hybrid photovoltaic thermal (PV/T) water collectors under constant collection temperature mode unlike constant flow rate mode. The analysis was carried out in terms of thermal energy, electrical energy and exergy gain for two different configurations namely case A (collector partially covered by PV module) and case B (collector fully covered by PV module) [1]. Bahaidarah et al. developed a numerical model (electrical and thermal) using EES (Engineering Equation Solver) software for performance analysis of a hybrid PV water system with cooling [2]. Chandrasekar et al. developed a simple passive cooling system with cotton wick structures for standalone flat PV modules. The thermal and electrical performance of flat PV module with cooling system

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Nomenclature

A	area (m^2)
C_p	specific heat (J/(kg K))
$\dot{E}_l$	rate of electrical energy (W)
$I(t)$	incident solar intensity (W/m^2)
$\dot{m}_w$	mass flow rate (kg/s)
$\dot{Q}_u$	rate of useful energy transfer (W)
T	temperature (°C)
P	power (W)
PV/T	photovoltaic and thermal

Subscripts

c	solar cell
a	availability
g	glass
i	inlet
m	module
o	outlet
sc	solar collector
th	thermal

Greek letters

α	absorptivity
δ	packing factor
η	efficiency
τ	transmissivity

consisting of cotton wick structures in combination with water, Al_2O_3/water nano fluid and CuO/water nano fluid are investigated experimentally [3]. Teo et al. designed and fabricated a hybrid photovoltaic/thermal (PV/T) solar system. To actively cool the PV cells, a parallel array of ducts with inlet/outlet manifold designed for uniform airflow distribution was attached to the back of the PV panel [4]. Sheyda et al. reported experimental data from performance of two-phase flows in a small hybrid micro channel solar cell. Using air and water as two-phase fluid, the experiments were conducted at indoor condition in an array of rectangular micro channels with a hydraulic diameter of 0.667 mm [5]. Moharram et al. developed a cooling system based on water spraying of PV panels. A mathematical model has been used to determine when to start cooling of the PV panels as the temperature of the panels reaches the maximum allowable temperature (MAT) [6].

In this study, as different from the literature new and more efficient PV/T system has been designed and experimentally analyzed. In the system, the PV module was placed on the front of the solar collector. The water was pre-heated in the PV module which was placed on the front of the solar collector. Also in this way PV modules were cooled.

Table 1
Description of measurement and control equipments.

Equipments	Properties
Danfoss solenoid valve	10 W power, 25 mm diameter
Ordell process control equipment	PC440, 4 W, 100–240VAC, transmitter supplement 24VDC
Haenni digital solar meter	Model-130 1500 W/m^2, sensitivity ±1.5%
Testo digital temperature sensor	Sensitivity ±0.005, LCD, −50 and 1000± °C interval. K type probe
Kyocera crystalline silicon solar module	54 W – 1000 W/m^2 25 °C, 38 W – 800 W/m^2 49 °C
Solar collector	Aluminum pipe, 0.5 m^2

2. Experimental system

The designed and experimentally analyzed system is given in Fig. 1 and Table 1. In addition, the flow scheme of the control system is given in Fig. 2. The cold water flowing into the system from "T_1" point in Fig. 1 passes through a transparent spiral pipe rolling behind the "PV Module" and gets out from "T_3" point. When the process control equipment "PCE" reaches the set temperature, it opens the "solenoid valve" which is normally off. The "temperature sensor" of the process control equipment is attached to the collector output. The water going to the "solar collector" fills the hot water in the "water depot" at the point of "T_4". When the "solar collector" temperature decreases under the set temperature,

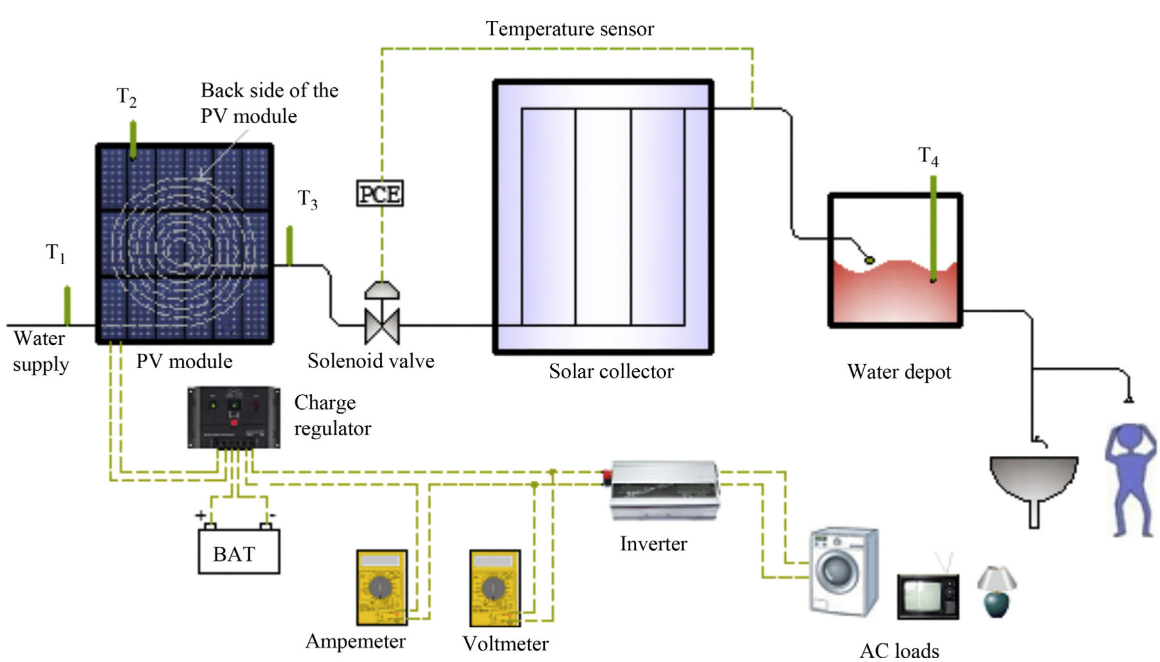

Fig. 1. Designed PV and thermal system.