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Modeling and parameter optimization of hybrid single channel photovoltaic thermal module using genetic algorithms

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Abstract

The PV research community and industry has major focus on the new advancement and improvement on power efficiency of PV systems. An attempt has been made to model and optimize the parameter of hybrid single channel photovoltaic thermal (PVT) module. In this paper it has been observed that there are many parameters that affect the electrical efficiency of a hybrid single channel PVT module like thickness of the glass and tedlar, temperature of the inlet flow, and solar cell temperature. All equations for solar cell and thermal collector have been derived. By using genetic algorithms (GAs), thermal efficiency and electrical efficiency of the system may be optimized. All the parameters that are used in genetic algorithms are the parameters that could be changed, and the non changeable parameters, like solar radiation cannot be used in the algorithm. It has been observed that the GAs are very efficient technique to estimate the design parameters of hybrid single channel PVT module.

Keywords: Genetic algorithms; Solar cell; Exergy; Energy

1. Introduction

Zhang et al. (2012) and Edmonds and smith (2011) concluded that the use of renewable energy came to existence due to lack of conventional power as compare to demand, most of the use of renewable energy is due to the negative effects brought out by global warming and climate change.

Kasaeian et al. (2013) and Venkateswarlu et al. (2013) reported that the advance of PVT technology in recent years has made solar energy sources available in the energy market. The PV research community and industry has major focus on the new advancement and improvement on power efficiency of PV systems. Lots of theoretical and experimental work has been done on PVT system and shown in the literature. The photovoltaic thermal (PVT) systems came into existence with an idea to utilize the thermal energy of the sun along with the electricity. Several theoretical and experimental studies of hybrid PVT systems exist. Zondag et al. (2002) have developed a model of a hybrid PVT air collector and performed experimental studies of such systems for varying sizes. Agrawal

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Nomenclature

A_{SC}	area of the solar cell, m^2
b	width of the channel, m
b_M	channel width of the module, m
d	depth of the channel, m
C_{air}	specific heat of air, J/kg K
dx	small length, m
dt	small time, s
h	heat transfer coefficient, W/m^2 K
h_{SCA}	heat transfer coefficients from solar cell to ambient through glass cover, W/m^2 K
h_{SCF}	heat transfer coefficients from solar cell to flowing air (fluid), W/m^2 K
h_{FA}	heat transfer coefficients from flowing air(fluid) to ambient, W/m^2 K
In	incident solar intensity, W/m^2
K_T	thermal conductivity, W/m K
L	length of the channel, m
L_M	channel length of the module, m
N_C	number of channel in SCPVT module
m_F	mass flow rate of fluid (air) in channel, kg/s
Q_U	useful heat, W
T_A	ambient temperature, K
T_{Avg}	average temperature, K
V_{air}	velocity of air, m/s
V_F	velocity of fluid (air) in channel, m/s
η_{TC}	efficiency at standard test condition when In = 1000 W/m^2 and T_A = 25 °C
n_R	number of rows in solar PVT module
β_0	temperature coefficient of efficiency, 1/K
$\eta_{C,power}$	power conversion factor
A_m	area of module
α	absorptivity
β	packing factor
η	efficiency
ρ	density, kg/m^3
T_{FI}	temperature of fluid at inlet, K
T_{FO}	temperature of fluid at outlet, K

Subscripts

A	ambient
C	channel
SC	solar cell
SCA	solar cell to ambient
SCF	solar cell to fluid
FA	fluid to ambient
T	thermal
Avg	average
TC	test condition
R	rows
F	fluid
FI	fluid at inlet
FO	fluid at outlet
eff	effective
U	useful

and Tiwari (2011a) have done performance evaluation of hybrid modified micro-channel solar cell thermal tile which was an experimental validation. Agrawal and Tiwari (2011b) have done experimental validation of glazed hybrid micro-channel solar cell thermal tile and concluded that the glazed hybrid micro-channel photovoltaic thermal (MCPVT) module gives higher electrical efficiency in comparison with single channel photovoltaic thermal (SCPVT) module by 26.7% and obtained 20.28% overall exergy efficiency. Agrawal and Tiwari (2011c) have presented the concept of series and parallel connections of micro-channel solar cell thermal tiles to analyze overall energy and exergy of hybrid micro-channel PVT module. Rajoria et al. (2012a) have done overall thermal energy and exergy analysis of hybrid PVT array and given four array configuration and concluded that case III is better than other cases. Rajoria et al. (2012b) have done exergetic and enviroeconomic analysis of novel hybrid PVT array. Agrawal and Tiwari (2012a,b) have done exergoeconomic analysis of glazed hybrid photovoltaic thermal module air collector and told that in terms of energy saving the glazed hybrid PVT module air collector offer a greater potential compared to PV module. Agrawal et al. (2012) have given the design and indoor experiment analysis of glazed hybrid photovoltaic thermal tiles air collector connected in series and concluded that if the numbers of glazed PVT tile are connected in series then it will be more beneficial from overall energy and overall exergy point of view. Agrawal and Tiwari (2012b) have done overall energy, exergy and carbon credit analysis on different type of hybrid PVT air collectors. Coventry (2005) has studied the performance of a concentrating PVT collector and concluded that an overall thermal and electrical efficiency of concentrating PVT system are 58% and 11%, respectively. This gives a total efficiency of the system as 69%. Exergy is a consistent measure of economic value as mentioned by the many researchers. The exergy based cost analysis is called exergoeconomic analysis (also known as exergetic cost analysis), as developed and utilized by many researchers for years Rosen and Dincer (2003). Tiwari and Sodha (2007) presented a variety of results regarding the effect of design and operation parameters on the performance of air type PVT systems. Tiwari et al. (2006) have validated the theoretical and experimental results for PV module integrated with air duct for composite climate of India and concluded that an overall thermal efficiency of PVT system is significantly increased (18%) due to utilization of thermal energy from PV module. Singh et al. (2012) have done