Journal of Physics and Astronomy

Hypothesis|Vol 9 Iss 12

Solar PV and Thermal (PVT) System: Fusion of Linear Fresnel Reflector (LFR) Concentrator

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Received date: December 2 ,2021; **Accepted date:** December 12, 2021; **Published date:** December 20 ,2021

Introduction

In recent years, solar energy-based power generation systems have gotten a lot of attention [1]. Concentrated solar thermal power [2] and Photo-Voltaic (PV) electricity production [3] are now the two most often employed technologies for large-scale solar power. Different concentration strategies can be used in PV electric power generation systems to boost solar intensity while reducing the number of PV cells. The Linear Fresnel Reflector (LFR) is a typical concentrator that can be used in both concentrated solar thermal power and concentrated solar photovoltaic systems [4]. The geometric concentration ratio of an LFR concentrator can be made to be high or small depending on the needs. Traditional LFRs' architectural characteristics can cause shade and blockage, as well as a problem with solar energy loss [5]. When using a standard LFR in a concentrating PV system, several design modifications should be considered in order to avoid shadowing and blocking problems to some extent.

Design Method of The PVT System

Overall Design

The PVT system mainly consists of four sections, including the solar concentrator, nano-fluids optical filter, PV device and the supplementary system (e.g., bracing structure, necessary pipelines). In this PVT system, the concentrator is selected to be an LFR, in which structural parameters of all mirror elements are modified and different from those in a traditional LFR. The PV device is assumed to employ the single crystalline silicon (c-Si) solar cell. The PVT system is symmetrical. A set of nano-fluids optical filter and PV panel is arranged on the solar receiver position of the LFR concentrator. The nano-fluids optical filter is an optical glass flow channel filled with flowing nano-fluids.

LFR Concentrator

This study provides a common design approach for LFRs, which can avoid shading and blocking phenomena to a certain extent. As the concentrator structure is axisymmetric, half of the solar field is taken as the example for the design method introduction. W stands for half of the concentrator width. The height and width of solar receiving surface are f and w. The tilt angle of solar receiving surface is α.

Experimental Study on the Nano-Fluids Optical Filter

For solar PVT systems, the beam splitting device is very important as it can directly influence the PV and thermal behaviours of the system. Different beam splitting strategies can be adopted according to the spectral response behaviours of different PV cells. For C-Si cells, the ideal PV window should be from 380.0 nm to 1100.0 nm. The PVT system proposed in the current study is designed to utilize the nano-fluids-based optical filter. The nano-fluids material is chosen to be the combination of Indium Tin Oxide (ITO) nano-particles and Ethylene Glycol (EG) in this study. The preparation and measurements of ITO nano-particles as well as the optical property test of the ITO-EG nano-fluids are carried out in this study. The molar ratio of In and Sn of the ITO nano-particles is 5:1. The base solution of the nano-fluids is the quadruple diluted ethylene glycol.

Conclusions

This study presents the design and investigation of a novel solar PVT system based on the combination of the LFR concentrator and ITO-EG nano-fluids optical filter. Preparation and relevant measurements of the ITO nano-particles as well as the ITO-EG nano-fluids are carried out. The test results reveal that the nano-fluids optical filter has an average absorptivity of 30.9% as well as an average transmittance of 69.1% in the solar spectrum range of 250.0 nm–2500.0 nm. Optical behaviour of the PVT system is estimated by using MCRT simulation method. The results indicate that the overall optical efficiency of the PVT system is 93.54%. Sensitivity analysis results of sun tracking error indicate that when the north-south direction tracking error is 0.2˚, the overall optical efficiency is 90.12%. That means the PVT system has a relatively good adaptive faculty when a reasonable sun tracking error occurs.

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