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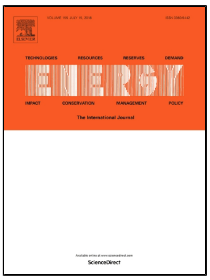

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Experimental and Numerical Investigation of Hybrid Concentrated Photovoltaic – Thermoelectric Module under Low Solar Concentration

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Abstract

The quick progress in solar energy technology has made it one of the most promising alternatives to conventional energy systems in recent years. In this work, in order to make efficient use of the solar energy, a hybrid system composed of the concentrated photovoltaic cell and thermoelectric generator (CPV-TEG) is studied using both experimental and numerical approaches. The experimental study is carried out under concentrated radiation of a solar simulator, and the numerical simulation is accomplished using finite volume method. The results are presented for various solar concentration (SC) values ranging from 8 suns to 37 suns. The variation of the temperatures, open circuit voltage, and short circuit current are discussed. I-V-P curves for both CPV and TEG are obtained and evaluated experimentally and numerically. The results show that contribution of the TEG in the total electrical power produced by the hybrid system enhances with increasing the solar radiation. Furthermore, the experimental results indicate that the maximum and minimum efficiency of the CPV is reached to 35.33 % and 23.02 %, while these values for the TEG are 1.20 % and 0.63 %, respectively.

Keywords: Concentrated Photovoltaic, Thermoelectric Generator, Solar Simulator, Lambert W Function, Newton–Raphson algorithm

1. Introduction

Nowadays, replacement of fossil fuels with renewable energies has become a vital need, where a significant global challenge is to encounter future energy demand in a renewable and sustainable way. Solar energy is a free, abundant and inexhaustible source of clean renewable energy that can be used to reduce the dependency on conventional fuels. In spite of the great improvement in photovoltaic (PV) technologies, the conversion efficiencies of PV systems need to be further improved. Due to higher efficiency in a smaller area, concentrated photovoltaics (CPVs) have attracted great attention from researchers recent years. The CPV cells can have high conversion efficiencies under concentrated sunlight. For instance, the efficiency of the four-junction cell of Fraunhofer Institute has reached to 46% at 508 suns [1, 2]. Nevertheless, more than half of the radiation is lost that can be recovered by thermoelectric generator (TEG). Having long lifetime and no moving parts and being highly reliable makes TEG an appropriate choice for energy harvesting from CPV cells [3].

Many studies have been considered the feasibility of using TEGs for harvesting the dissipated heat from the PV cells [4-8], but few studies considered coupled effect of CPV-TEG hybrid systems. Sweet et al. [9] investigated a hybrid CPV-TEG system, and found that using the thermoelectric module for cooling, improves CPV cell efficiency, fill factor and power generation. Rezania et al. [10] investigated a hybrid PV-TEG system and showed that, with present thermoelectric materials the contribution of the TEG power in overall power produced by the PV-TEG system is very small. Although, in another study, Rezania and Rosendahl [11]

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