Solar Energy 185 (2019) 480–493

Contents lists available at ScienceDirect

Solar Energy

journal homepage: www.elsevier.com/locate/solener

Thermal and economic assessment of a solar chimney cooled semi-transparent photovoltaic (STPV) power plant in different climates

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ARTICLE INFO

Keywords:
Semi-transparent PV
Solar chimney
Cooling enhancement
Economic evaluation
Thermal analysis

ABSTRACT

A new cooling approach for a semi-transparent photovoltaic system using a solar chimney (STPV-SC) is proposed and economically evaluated. The STPV panels are utilized as the collector roof of a solar chimney for enhancing the panels cooling. For analyzing the system, a mathematical model based on the heat transfers between three main components of system: STPV, inside air and ground is developed and the results are validated by the experimental data reported in the literature. Furthermore, a comprehensive economic evaluation is carried out for the proposed system and payback period, as well as unit cost of produced power, are reported as the main economic parameters. The influence of main decision variables including packing factor, chimney height and collector radius is investigated on the power generation and economic performance. Moreover, the economic assessment of proposed system is carried out for five selected cities in Iran. Based on the results, packing factor always optimizes the economic performance, whereas the lowest payback period is obtained for packing factors between 0.3 and 0.5. Also, it is found that the highest and lowest economic enhancements by using the proposed system belong to Shiraz and Tabriz cities with about 11% and 5%, respectively.

1. Introduction

Energy is a key factor for sustainable development of any country. It is predicted that the global energy consumption in 2035 will reach around 32.922 TW which is about twice of that in 2008 (Alamdari et al., 2013). Nowadays, about 75% of the global energy consumption is supplied by fossil fuels causing climate changes and several environmental issues (Preet, 2018). Renewable energy resources, however, are sustainable and are free of environmental issues (Nemati et al., 2018).

It is estimated that the renewable energy can meet the current world energy needs by more than 3000 times with more than 93% from solar energy (Ellabban et al., 2014).

Iran is very rich in both oil and natural gas, which holds nearly 10% of the crude oil as well as 17% of the world natural gas reserves (Najafi et al., 2015). Energy production in Iran heavily depends on fossil fuels making it among the 20 countries producing the highest levels of greenhouse gas emissions (Alamdari et al., 2013). Fortunately, Iran has abundant solar energy resources with more than 300 sunny days per year in the most of the country and annual irradiation levels of 1800–2200 kWh/m^2, which is higher than the global average (Firouzjah, 2018).

PV system is the most widely used technology utilizes the solar energy (Akrami et al., 2018). Using semiconductor materials, a PV device converts the sunlight energy directly to the electricity. The sunlight contains photons which are absorbed by the PV causing electron ejection and enables an electron flow which forms an electrical current. This is named the photovoltaic effect. The PV cells are manufactured using different methods and materials so that there are more than 20 types of the cells (Husain et al., 2018). Lunt and Bulovic (2011) demonstrated Organic PV (OPV) cells. The excitonic property of organic semiconductors allows producing photovoltaic architectures that cannot easily be produced with inorganic semiconductors. They reported that these cells in a series-integrated array are capable of producing power under near-ambient lighting. Lunt et al. (2011) in another paper discussed practical aspects and limitations of nanostructured photovoltaics. The challenges associated with increasing the efficiency of various nanostructured photovoltaics as well as several approaches to reduce thermal losses are reviewed. Sun and Jasieniak (2017) performed a topical review of semi-transparent solar cells. These cells combine the advantages of visible light transparency and converting light-to-electricity, and can be integrated with the building's windows and skylights. The paper reviews current developments about the major types of semi-transparent solar cells as well as their benefits and building-integrated features. Shyam and Tiwari (2016) performed an energy and economic analysis for series connected PVs which are partially covered by the semi-transparent photovoltaic module. Two cases

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https://doi.org/10.1016/j.solener.2019.04.073
Received 3 August 2018; Received in revised form 23 April 2019; Accepted 24 April 2019