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Modelling and simulation of concentrating photovoltaic system with earth water heat exchanger cooling

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Abstract

In the present paper, a novel cooling system for concentrating photovoltaic (CPV) which is termed as earth water heat exchanger (EWHE) is modeled and simulated for local conditions of Pilani, Rajasthan. The CPV temperature and power output are obtained with respect to variation in mass flow rate of fluid and concentration ratio (CR). The simulation results shows that the maximum CPV temperature goes up to 416.36 °C at 3 Suns without any cooling, while with cooling it is reduced down to 85.28 °C for the mass flow rate of 0.022 kg/s. CPV temperature drop and power output increases with increasing in mass flow rate when it operated with EWHE in a closed loop. The mass flow rate of 0.022 kg/s is estimated as suitable flow rate as it may be used for the practical applications. It is also observed that with increase in mass flow rate the outlet temperature of CPV/T decreased.

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1. Introduction

Among various renewable energy sources, Solar energy has a huge potential to overcome energy demand, due to its abundant availability [1-2]. The energy from the sun can be harnessed in the form of either heat, like solar thermal, or electricity like photovoltaic (PV) and is termed as clean energy. PV technology is quite mature

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technology and enjoys long and wide field experiences all over the world [3-5]. However, with the requirement of large area of the PV, the cost of this technology is still on the higher side when compared with traditional power generation sources. The generation cost of SPV can be minimized if the smaller area is used for same power output. This can be done by using concentrating photovoltaic (CPV) in which solar radiation is concentrated with the help of mirrors or lenses to focus the sunlight on a smaller area [6]. Such systems are classified according to the number of times, the radiation is focused to a particular point, which is termed as Concentration Ratio (CR) and usually referred as 'Suns'.[7]. But the main problem with the CPV system is that with increase in CR, the cell temperature increases and this temperature growth leads to reduction in the cell efficiency and may damage the cell's integrity. If the temperature increased to a certain limit the cell's life-span would reduce rapidly [8-9], so proper cooling system is required to maintain the temperature within the limits.

Many researchers have worked on various CPV cooling techniques. When PV cells are coupled with thermal collectors so that the concentrated solar energy can produce both thermal and electrical power, the system is termed as concentrating photovoltaic/thermal (CPV/T) systems [10-11]. Such technology has been discussed in the literature for various applications, like water heating [12], air heating [13], desalination [14] etc. Coventry [15] investigated the performance of a CPV/T collector where the row of cells were cooled by fluid flowing through an aluminum tube which has finned internally. Renno and Petito [16] presented a research on domestic application based CPV/T system which works on 900 Suns. They obtained the CPV/T outlet temperature as 90 °C which can be used to run an absorption heat pump for cooling during summer period. Helmers et al. [17] presented an energy balance model for the CPV/T system. They found that for higher CR, the electrical efficiency increases and the thermal losses decreases. Mittelman et al. [14] proposed a coupled system of multiple effect evaporation with CPV/T to generate both electric power output and desalinated water.

The cooling of CPV cells can be achieved by coupling it with geothermal cooling system. Geothermal cooling works on the concept that at a certain depth, the soil temperature remains almost constant throughout the year and is approximately equals to the mean surrounding temperature over a year. So the soil can be used as a thermal sink for the cooling of CPV/T system[18]. Various researchers have used earth water heat exchanger (EWHE) and earth pipe air heat exchanger for air conditioning using water and air as a cooling medium respectively [19-22]. The EWHE pipes are buried below the ground to a particular depth, and the inlet of the pipes carries the hot water which transferred the energy from the high temperature fluid to the soil, thus resulting in the decrease in outlet temperature [23-25]. The present research work deals with the utilization of geothermal cooling principle for the removal of waste heat of CPV/T thus providing a new cooling technique. The objective of this paper is to provide transient investigation of coupled CPV/T and EWHE system using TRNSYS (v17.0) by modelling and simulation for peak summer duration of Pilani, Rajasthan.

2. Modelling and simulation of CPV/T system with EWHE

The proposed system is modeled and simulated for the Pilani region of Rajasthan, India using TRNSYS software. TRNSYS is a transient analysis simulation tool for the study of renewable energy systems [26]. The simulation of CPV/T coupled with EWHE requires climatic data such solar radiation, wind velocity, ambient temperature, relative humidity etc. Weather data for Pilani, Rajasthan (India) have been generated using inbuilt Meteonorm files provided within TRNSYS. Soil properties like density and thermal conductivity have been determined using available testing standards. The simulation model consists of components (called as Types) which are inbuilt and can be linked to other Types and takes time dependent inputs and technical parameters to give transient output. Fig. 1 represents the simplified flow diagram for the coupled system under consideration for this research.

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