Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 90 (2016) 145 – 153

Energy Procedia

5th International Conference on Advances in Energy Research, ICAER 2015, 15-17 December 2015, Mumbai, India

# Performance analysis of earth water heat exchanger for concentrating photovoltaic cooling

Sanjeev Jakhar, M.S.Soni*, Nikhil Gakkhar

*Centre for Renewable Energy and Environment Development (CREED), Department of Mechanical Engineering, Birla Institute of Technology and Science, Pilani, Rajasthan, India 333031*

**Abstract**

In the present work, an earth water heat exchanger (EWHE) has been designed for Pilani, Rajasthan (India). The system is designed and simulated in transient analysis tool TRNSYS (v17.0) by varying its operating parameters which includes mass flow rate, length, pipe materials and diameter of buried pipe. The depth-wise temperature of soil has also been evaluated from the simulation and it is found that the depth of 3.5 m is sufficient for pipe burial. The results show that there is an inverse correlation between the pipe length and the EWHE outlet temperature. The comparative study between three different material shows that the performance of EWHE system hardly depends on the properties of these material. Further, the EWHE performance is found to be decreasing with an increase in the mass flow rate from 0.008 kg/s to 0.05 kg/s. The simulated proposed system is then compared with the existing ones in the literature for a given cooling setup of Concentrating Photovoltaic (CPV). It is observed that the proposed system gives better performance than the cooling system given in literature. To achieve the temperature drop from 48.5 °C to 25.5 °C as per the existing CPV setup in the literature, the pipe length of 60 m would be sufficient in the proposed EWHE system. Thus the coupling of EWHE with CPV plants could be economical as well as performance enhancer.


Peer-review under responsibility of the organizing committee of ICAER 2015

*Keywords:* Earth Water Heat Exchanger; TRNSYS (v17.0); Parametric variation; Concentrating Photovoltaic.

* Corresponding author. Tel.: (+91) 1596-515634; fax: (+91) 1596-244183.
*E-mail address:* mssoni@pilani.bits-pilani.ac.in


Peer-review under responsibility of the organizing committee of ICAER 2015
doi:10.1016/j.egypro.2016.11.179

## 1. Introduction

In geothermal cooling principle, the temperature of the soil at the burial depth of about 3.5 m or more remains almost constant throughout the year, which is around the average annual ambient air temperature [1]. Specially in peak summer in dry and arid areas like Rajasthan and Gujarat, due to high solar insolation, ambient temperature reaches about 47 ºC during daytime [2,3]. For such areas geothermal cooling may be considered to be a very good alternative for cooling purpose. Some researchers have used earth air pipe heat exchanger (EAPHE) for air conditioning [4-8]. Bansal et al. [9] presented a model for EAPHE and experimentally validated it. They found that the performance of EAPHE does not depend on buried pipe material. Jakhar et al. [10] evaluated the performance of the EAPHE with solar air heating duct for winter heating. They concluded that the COP of system increased up to 4.57 when coupled with solar air heating duct. However, the challenge with EAPHE is that it requires large surface area for effective heat transfer because of low thermal conductivity and low heat carrying capacity of air. The required surface area may be reduced by using water as cooling medium in EWHE because of its high heat transfer capacity. In this system, the pipes carry hot water instead of air which are buried at a certain depth below the ground, and act as a heat exchanger, where heat transfer take place between hot water to the earth thus decreases the outlet temperature of water. This outlet water from buried pipes may be used for space cooling with the help of a compact heat exchanger. Joen et al. [11] presented an analytical model for comparison the performance of EAPHE and EWHE. They calculated that the soil resistance is more dominant in case of EWHE and required small diameters tubes for effective heat transfer. Chel et al. [12] investigated the performance of an integrated system of EWHE, water air heat exchanger and air to air heat exchanger (AAHE) with the help of TRNSYS 17. They found that the integrated system together could reduce the annual heating consumption of the building by 72 %.

In the current work an attempt has been made to use EWHE for cooling of CPV cells. In such EWHE system, performance depends on various parameters which include mass flow rate of the water, depth of buried pipe, length, diameter and material of pipe, etc. By changing these parameters, the variation in outlet temperature of EWHE can be achieved. This study presents the variation in these parameters to achieve optimum EWHE outlet temperature. Further, the applicability of such proposed system is discussed by replacing the system given in literature of CPV [13, 14]. The operating temperature of the CPV system, as discussed by [15-18] is the key parameter affecting its performance, as with rise in temperature beyond certain limit results in decrease in efficiency. Hence, it is must to maintain the temperature within certain limit to achieve higher efficiency. The results obtained from the simulations shows that the proposed system performs better by giving sufficient temperature drop than the cooling system given in literature.

## 2. Description of the TRNSYS simulation

TRNSYS, a transient simulation system tool is used to model the renewable energy systems to estimate the transient variation [19]. Using this tool numerical simulation of the EWHE was carried out by using its inbuilt Meteonorm files for weather conditions. The model design includes inbuilt system components which take parameters and time dependent inputs of desired system and produces a time dependent outputs. Various components, which are designated as Type, can be interconnected with a flow chart. Here a given output of one component is used as an INPUT to a number of other components. In the current system the model for EWHE was used to estimate the transient output over a period of time.

The different TRNSYS component models (Types) which were used in the simulation are:

- Type 77- Simple ground temperature model
- Type 952- Earth water heat exchanger
- Type 3- Variable speed pump
- Type 15 - Weather data processor
- Type 65- Online plotter

Type 952 is important models in ground heat pump library of TRNSYS which models a horizontal heat exchanger that interacts thermally with the ground. It considers conductive heat transfer to the soil and convective heat transfer within the pipes. For the simulation, the physical and thermal parameters of the system taken are shown in Table 1.