INTERNATIONAL JOURNAL OF REFRIGERATION 76 (2017) 328–341

Available online at www.sciencedirect.com

ScienceDirect

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

Numerical and experimental study of a closed loop for ground heat exchanger coupled with heat pump system and a solar collector for heating a glass greenhouse in north of Tunisia

*S. Awani *, S. Kooli, R. Chargui, A. Guizani*

Centre de Recherche et des Technologies de l'Energie (CRTEn), PB 95, Hammam Lif 2015, Tunisia

A R T I C L E I N F O

Article history:
Received 20 July 2016
Received in revised form 24 December 2016
Accepted 30 January 2017
Available online 6 February 2017

Keywords:
Heat pump
Ground heat exchanger
Fate plat collector
Greenhouse
TRNSYS

A B S T R A C T

This work emphasizes the exploitation of renewable energy sources for heating a greenhouse, which requires the use of a horizontal heat exchanger, a heat pump associated with a solar collector in numerical and experimental investigations. This study demonstrates the performance of a heat pump system assisted by solar and geothermal energy under the climatic conditions of Tunisia. This system was designed and installed in Thermal Process Laboratory; Research and Technology Centre of Energy CRTEn Borj Cedria. The surface area and of the glass greenhouse used in the experimental model are 14.8 m^2 as surface area. We precede several experimental data for realizing a numerical model based on TRNSYS software. For this point of view a numerical model was improved using 100 m^2 and 229.5 m^3 as surface and volume areas. The water-air heat pump is coupled with a ground heat exchanger (GHE) with 1m of depth. The distance between two consecutive tubes is 0.3 m. The surface area of the solar collector is 8 m^2.

Étude numérique et expérimentale d'une boucle fermée pour un échangeur de chaleur géothermique couplé à un système de pompe à chaleur et un capteur solaire pour chauffer une serre en verre au nord de la Tunisie

Mots clés : Pompe à chaleur ; Échangeur de chaleur géothermique ; Capteur à surface plane ; Effet de serre ; TRNSYS

* *Corresponding author.* Centre de Recherche et des Technologies de l'Energie (CRTEn), PB 95, Hammam Lif 2015, Tunisia. Fax: +216 79 325 825.

E-mail address: sami.awani1985@gmail.com (S. Awani).

http://dx.doi.org/10.1016/j.ijrefrig.2017.01.030
0140-7007/© 2017 Published by Elsevier Ltd.

Nomenclature

A	collector area [m^2]
A_1,A_2	surface area of various components in greenhouse [m^2]
COP	coefficient of performance (–)
COS(φ)	the power factor (–)
C_p	specific heat of water at constant pressure [KJ $Kg^{-1}K^{-1}$]
Cpf	specific heat of collector fluid [KJ Kg^{-1} K^{-1}]
f_c	construction type of quality factor for greenhouse (–)
fs	system factor for greenhouse (–)
f_w	wind or exposure factor for greenhouse (–)
$H_{1,2,3,4}$	enthalpy in evaporator, condenser, compressor, holder [J Kg^{-1}]
I_{com}	the current of the compressor [A]
I_T	global radiation incident of the solar collector [KJ h^{-1} m^{-2}]
L	length [m]
$\dot{m}$	mass flow rate [Kg hr^{-1}]
$\dot{m}_{rg}$	mass flow rate of refrigerant R134a [Kg hr^{-1}]
Q_c	the useful heat of the condenser [KJ hr^{-1}]
$\dot{Q}_{com}$	the useful heat of the compressor [KJ hr^{-1}]
Q_{ev}	the useful heat of the evaporator [KJ hr^{-1}]
Q_{exp}	the experimental heat exchange rate [W]
$\overline{Qe}_{exp}$	the heat exchange rate per unit length [W]
Q_u	the useful heat that is received from the collector [KJ hr^{-1}]
Q(MAX)	the theoretically possible of maximum heat exchange rate [W]
$\dot{Q}_{GHL}$	the heat loss [KJ hr^{-1}]
R_1,R_2	thermal resistance of each component in greenhouse [m^2 °C W^{-1}]
T	temperature [°C]
V_{com}	the voltage of the compressor [V]
W_{com}	the power of the compressor [W]

Greek letters

ε	exchanger energy efficiency (–)
η	collector efficiency (–)

1. Introduction

Based on the studies of the renewable energetic aspects of the agricultural and residential building heating systems which have appeared in the open literature, we can conclude that solar energy and the geothermal surface of water are great interests in this field.

In literature, there are many reported theoretical and experimental studies, which explain the thermal energy and the solar energy accumulated in the soil and coupled with a horizontal heat exchanger may be used for heating the greenhouse system. A real success of solar integrated energy system requires a good solar cooling and heating system, Badran et al. (2004) have illustrated an experimental study for an inverted trickle solar still. The two identical flat plate collectors of the conventional fin tube configuration was developed by Badran and Jubran (2001). Numerical simulation, technical and economic evaluation, and aspects of air-to-earth heat exchangers was investigated by Bojić et al. (1999) and Kuang et al. (2003). Many experimental studies have reported various types of research classified in three groups as follows: (i) solar collectors coupled with a heat pump system associated with a single zone, (ii) heat exchanger coupled with a heat pump, (iii) solar collectors coupled with a heat exchanger and a heat pump for heating the greenhouse. In reference Bakirci(2010), Esena et al. (2007), and Ozgener and Ozgener (2010a, 2010b) an experimental study in the area "heating a greenhouse for the Mediterranean climate using the underground air tunnel system coupled with a flat plate solar collector" or "a vertical-horizontal heat exchanger coupled with a heat pump and a greenhouse system". Ozgener (2010) and Ozgener and Ozgener (2010a) concluded that her system can provide 60, 8% on the need of thermal energy. The experimental results provided in Bakirci(2010) and Esena et al. (2007) show that the average values of the COP of the heat pump and the COP_{syst} of the global system varied between 3 and 2.6. The cooling of the glass greenhouse using the coupling of the heat pump and the storage tank was assured in Yang and Rhee (2013). The comparison of the experimental results between the coupling of the heat pump system associated with a vertical heat exchanger and a heat pump system associated with a horizontal heat exchanger was evaluated in Benli(2013) and Petit and Meyer (1997) and improved by the integration of the solar energy in Kuang et al. (2003). The heat pump and the storage tank related with a thermostatic valve that has a capacitance equal 150 L was presented and was analyzed in Li et al. (2007). The performance of the heat exchanger was also evaluated and was discussed in the research of Esena et al. (2007), when they found that increasing the depth ameliorates the performance of this component. The solar collector coupled with a heat exchanger and a heat pump system presented by Chaturvedi et al. (2009), Esen and Yuksel (2013), and Gorozabel Chata et al. (2005), is an example very close to our work, the performance of geothermal heat pump in the night was evaluated. The research made by Çakır et al. (2013), Kwon et al. (2013), Moreno-Rodriguez et al. (2013), and Wood et al. (2010) is based in a experimental study which examines at each time the performance of the heat pump in the installation. A compression heat pump and a geothermal heat pump have been used for heating a residential building (Kwon et al., 2013; Wood et al., 2010). With the same climatic conditions, the heat pump working with more sources in the level of the evaporator was compared in Çakır et al. (2013). The air–air heat pump, the water–air heat pump, the water–water heat pump and the air water heat pump have been tested in Çakır et al. (2013). A heat pump with a nominal capacitance assisted with a solar collector and a geothermal heat pump coupled with a vertical heat exchanger have been studied and analyzed with the experimental data in Moreno-Rodriguez et al. (2013).

In addition, numerical studies have been developed to ameliorate the research in the scope "modeling and simulation a heat pump coupled heat exchanger associated with building systems". Recently Chargui et al. (2012, 2014) have ameliorated a numerical study on TRNSYS software which is based on ameliorating the performance of the heat pump for heating the agricultural greenhouse or residential building. In the same field, Awani et al. (2015) studied the heating of two types of green-