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Geothermal heat pump in heating mode: Modeling and simulation on TRNSYS

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ABSTRACT

The consumption of energy in greenhouses and residential buildings has gained an increasing interest. Recently, due to the rising demand for efficient energy use and higher comfort standards, our contribution will relate to an application of heating of a greenhouse by using an abundant and more universal sources and easily accessible. Thus, the resources employed are water or air. The objective of this work is to model and simulate a heat pump on TRNSYS which is dedicated to study the thermodynamic phenomena. Here, we present a mathematical description of the heat pump on TRNSYS model by using HVAC technique, as well as the numerical results of the simulation of the heat pump, such as the COP, power consumption and the delivered power, by using the geothermal source in southern Tunisia.

Pompe à chaleur géothermique en mode chauffage: Modélisation et simulation sur TRNSYS

Motsclés : Pompe à chaleur ; Chauffage ; Simulation ; Coefficient de performance ; Puissance

1. Introduction

In Tunisia, due to lack of notoriety, geothermic is slightly used like many renewable resources. Compared to other countries, in these times of safeguarding of energy, the evolution of renewable recourse is significant and it occupies in the world one of the first place of renewable energies. The geothermal sources in Tunisia (the water of surfaces, the water of the wells…) are used for heating and cooling of greenhouses, by using geothermic heat pumps. This thermodynamic system

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Nomenclature

C_{pf}	Specific heat liquid source (kJ kg^{-1} K^{-1})
$\dot{m}_i$	Inlet flow rate of water heat source (kg h^{-1})
$\dot{m}_0$	Outlet flow rate of water heat source (kg h^{-1})
$\dot{Q}_{abs}$	Absorbed power by the evaporator (kJ h^{-1})
$\dot{Q}_{dh}$	Delivered power to room by direct liquid source heating (kJ h^{-1})
$\dot{Q}_{ei}$	Electrical power consumed by heat pump (kJ h^{-1})
$\dot{Q}_{hp}$	Delivered power by heat pump (kJ h^{-1})
T_a	Ambient Temperature (°C)
T_{dh}	Minimum fluid source temperature necessary for direct liquid heating (°C)
T_i	Inlet temperature of water heat source (°C)
$T_{min,a}$	Minimum ambient temperature necessary for heat pump operation (°C)
$T_{min,i}$	Minimum fluid temperature necessary for heat pump (°C)
T_0	Outlet temperature of water heat source (°C)
T_R	Temperature of room air heated by heat pump or directly by the liquid source (°C)
C_{min}	Effectiveness times minimum capacitance of heat exchanger for direct liquid source heating (kJ h^{-1} K^{-1})
Q_{hp}	Capacity of the heat pump (kW)
P_{hp}	Electric power consumption of the heat pump (kW)

Abbreviations

COP	Coefficient of Performance
TRNSYS	TRaNsient SYstem Simulation program
HVAC	Heating Ventilating Air Conditioning
EES	Engineering Equation Solver

Greek letters

γ_{htr}	Control function for heat pump (0 − off, 1 − on)
ε	Heat exchanger effectiveness

Subscripts

abs	Absorbed
ei	Electrical
dh	Delivered; Heating
hp	Heat pump
min	Minimum
a	Ambient
i	Inlet
0	Outlet
R	Room

includes two heat sources (hot and cold) between which a coolant that (R-134a, R-410, R-22, CO_2…) undergoes a cycle of transformations, causing a heat transfer between the two sources. We attend a heat transfer of hottest medium about the coldest middle, whereas spontaneously heat diffuses hotter toward coldest until the equality of the temperatures. This machine restores more energy, and hence, after this foreword we expose some work available in the literature which treats the heat pumps.

Haberschill et al. (2006) have developed a prototype of heat pump to CO_2 (water/water) functioning with a hermetic compressor to raise the temperature of a domestic hot water from 13 to 60 °C. The results show that the COP of the transcritical heat pump is 10% superior to that of R-22. Various types of compressors have also been studied. It is the case of compressors screw and spiral (Klidonas, 2005; Winandy and Hundy, 2004). The installation on which Saikawa and Hashimoto (1998) made experiments function with a compressor twin-cylinder. The regulation is made either by the valve located downstream from the evaporator, or by the number of revolutions of the compressor. From their side, Ozgener et al. (2007) have presented a parametric study on the exergoeconomic assessment of a vertical ground-coupled (geothermal) heat pump system. They have made a parametric study to investigate how varying reference temperatures will affect the exergoeconomic analysis of the ground-source heat pump system. A correlation between the ratio of thermodynamic loss rate to capital cost and reference state temperature is developed. Slim et al. (2008) have studied the modeling of a solar and heat pump sludge drying system. This paper focuses on the evaluation of the heating temperature leading to an annual thermo-economic optimum in terms of energy consumption. This article presents a very developed theory; the COP of the pump exceeds value 5, which explains the interest of this work. Recently, Ozcan and Ozgener (2011) have studied the geothermic heat pumps. This study highlights theoretical, energetic and exergetic performance evaluation results of Bethe–Zeldovich–Thompson (BZT) fluids in geothermal heat pumps. In this study, they have selected hexafluoroethane (R-116), octafluoropropane (R-218), and octafluorocyclobutane (RC318) as possible alternative replacements to the traditional refrigerants in geothermal heat pumps. In addition, Ozgener and Hepbasli (2007) have developed the modeling and performance evaluation of ground source (geothermal) heat pump systems. In this study the results obtained is discussed in terms of energetic and exergetic aspects. The values for COP_{HP} ranged from 3.12 to 3.64, while those for COPsys varied between 2.72 and 3.43. Furthermore, Manole (2004) have proposed to take the maximum temperature of the cycle as a parameter of adjustment. From their side, Neksa et al. (1998) have carried out experiments on a prototype of heat pump, intended for the production of hot water and controlled by computer acting on a pneumatic pressure reducer and the number of revolutions of the compressor. They highlight the difficulty of this process for which a reliable modeling of the complete system is necessary. This last point has been confirmed recently by Rasmussen et al. (2005).

In the field of modeling, much of studies aiming at the optimization of operation in nominal mode were made. We can in particular quote that of Sarkar et al. (2006) based at the same time on energy and exergetic analyses. Among the authors who have sought to model the operation of the PAC in dynamic mode, we can quote Skaugen and Svensson (1998) and Bryan and Andrew (2004) who have presented a model of simulation with discretization of the heat exchangers, but