Applied Thermal Engineering 103 (2016) 377–390

Contents lists available at ScienceDirect

Applied Thermal Engineering

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

Research Paper

Dynamic simulation of a solar heating and cooling system for an office building located in Southern Italy

Giovanni Angrisani [a], Evgueniy Entchev [b], Carlo Roselli [a,*], Maurizio Sasso [a], Francesco Tariello [a], Wahiba Yaïci [b]

[a] Università Degli Studi Del Sannio, Dipartimento di Ingegneria, Piazza Roma 21, Benevento, Italy
[b] CanmetENERGY, Natural Resources Canada, 1 Haanel Drive, Ottawa, ON, Canada

HIGHLIGHTS

- Solar heating and cooling system based on adsorption chiller is considered.
- Thermo-economic analysis on solar heating and cooling system for office building.
- Sensitivity analysis varying collectors, tilt angles, aperture areas, storage sizes.

ARTICLE INFO

Article history:
Received 25 January 2016
Revised 6 April 2016
Accepted 19 April 2016
Available online 20 April 2016

Keywords:
Solar cooling
Solar heating
Adsorption chiller
Dynamic simulation

ABSTRACT

The paper investigates the introduction of a solar heating and cooling system in an office building characterized by low energy demand with respect to the current national building stock and located in Southern Italy. Dynamic simulations are carried out in order to evaluate the thermo-economic performance of the analyzed system considering different solar panel technologies (flat plate and evacuated tube), tilt angles (10–70°), collecting areas (30–60 m^2), hot and cold storage sizes, reference emission factors, electricity and natural gas unitary prices. To satisfy cooling demand a small scale adsorption chiller activated by thermal energy available from solar collectors is considered.

The solar heating and cooling system demonstrated primary energy saving and equivalent dioxide carbon emission reduction higher than 23% in comparison to the reference conventional system. The results show that the solar energy system will be competitive when the electricity and natural gas prices will be high and strong government incentives will be provided.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

The energy consumption in residential and commercial buildings represents around 40% of total final energy use of European Union, being responsible of 36% of total CO_2 emissions [1]. Between 40% and 80% of this energy is used for heating or cooling purposes and this demand is usually satisfied by electrically driven units leading to high electric consumption. This trend is determining increasing interest in those technologies able to shift energy demand in summer from electricity to other sources that are widely available, efficiently exploitable and with low or negligible environmental impact. For this reason attention should be paid in this sector to reduce primary energy consumption due to fossil fuel and equivalent CO_2 emissions related to space heating and cooling. Different ways could be considered in order to reach this aim and the most common techniques are:

- interventions on opaque and transparent building envelope reducing transmittance;
- introducing high efficiency energy conversion systems, such as condensing boiler, cogenerator, gas engine driven heat pump, ground source heat pump;
- introducing renewable energy system based on solar thermal collectors considering different technologies such as flat plat collectors (FPC), evacuated tube collectors (ETC), and compound parabolic concentrators (CPC);
- solar electric driven system [2]: solar PV (photovoltaic) collectors interacting with a space heating and cooling system based on an electric heat pump;

* Corresponding author.
E-mail address: carlo.roselli@unisannio.it (C. Roselli).

http://dx.doi.org/10.1016/j.applthermaleng.2016.04.094
1359-4311/© 2016 Elsevier Ltd. All rights reserved.

Nomenclature

A_g	gross collector area (m^2)
A_n	net collector area (m^2)
a_1	efficiency slope ($W/(m^2\,K)$)
a_2	efficiency curvature ($W/(m^2\,K^2)$)
C	valorization coefficient (€/m^2)
CO_2	CO_2 equivalent emission (kg/y)
COP	coefficient of performance (–)
c_u	unitary cost (€/N m^3, €/kW h)
E	energy (kW h/y)
EC	extra cost (€)
EER	energy efficiency ratio (–)
$FESR$	fuel energy saving ratio (%)
F	cash flow per year (€/y)
g	total solar energy transmittance (–)
HDD	Heating Degree Day (°C)
k	thermal conductivity (W/m K)
$I_{a,tot}$	annual incentive (€/y)
IC	investment cost (€)
LHV	lower heating value (kW h/N m^3)
N	number of years (y)
N_C	net capacity (l)
OC	operating costs (€/y)
SF	solar fraction (–)
SIC	specific investment cost (€/m^2)
U	overall heat transfer coefficient ($W/m^2\,K$)
$UFES$	unitary fuel energy saving (kW h/m^2 y)
$UFiES$	unitary final energy saving (kW h/m^2 y)
$U\Delta CO_2$	unitary avoided equivalent CO_2 emissions (kg/m^2 y)
V	volume (N m^3/y)

Greek symbols

α	emission factor for electricity drawn from grid (kg CO_2/kW h_{el})
β	emission factor for natural gas (kg CO_2/kW h_{EP})
ΔCO_2	CO_2 equivalent avoided emission (%)
ΔOC	difference in terms of operating costs (€/y)
η	efficiency (–)
η_0	intercept efficiency (–)

Subscripts

aux	auxiliaries
co	cooling
EG	electric grid
el	electric
h	heating
in	inlet
NG	natural gas
p	primary
SS	solar system
Sun	sun
th	thermal
tot	total
US	end user

Acronyms

ADHP	adsorption chiller
B	boiler
CH	electric chiller
CPC	compound parabolic collector
CS	conventional system
CST	cold storage tank
DC	dry cooler
ETC	evacuated tube collector
FPC	flat plate collector
HST	heat storage tank
P	pump
PS	proposed system
PV	photovoltaic
PV/T	photovoltaic/thermal
SC	solar collector
SHC	solar heating and cooling
SPB	simple pay back
TRNSYS	transient system simulation
WC	wet cooler

- solar thermal assisted electric heat pump: thermal energy available from solar collectors used to operate an electric heat pump at lower evaporating temperature [3];
- a combination of renewable energy based and high energy conversion efficiency technologies [4–6].

In the last years great attention has been given to solar heating and cooling (SHC) systems in order to increase the use of thermal solar-based technologies in residential and commercial buildings. There are different types of SHC plants based on several thermally-driven refrigeration devices [7]: absorption [8,9] and adsorption heat pumps [10], ejector refrigeration systems [11], desiccant [12] and evaporative cooling systems. In Ref. [13] the authors report a review of solar-powered refrigeration plants considering absorption and adsorption systems and their main applications.

For small scale applications, the required temperature from thermal energy source is in the range 55–95 °C suitable to be reached by solar collectors system [14]. Small scale absorption and adsorption heat pumps are still at research and development phase and only a few and expensive models are commercialized [15]. The most popular technology used in solar cooling systems is based on absorption chiller that works with a higher temperature than those based on adsorption system [16]. Adsorption chiller using zeolite–water and silica gel–water as working pair could increase the range of applications of solar cooling systems thanks to low activation temperature starting from 55 °C. Different solar-based adsorption system configurations could be considered: some researchers proposed compact design integrating solar collectors in thermally activated chiller. Ammar et al. in Ref. [17] simulated an adsorption refrigeration system integrating a tubular solar collector/adsorber based on activated carbon–methanol as a working pair.

Gonzales et al. in Ref. [18] experimentally analyzed a solar adsorption chiller based on CPC collectors whose tubular receiver contains the sorption bed using activated carbon–methanol as working pair. Other researchers focused the analysis on more flexible configurations in which solar collectors are separated by adsorption chiller.

Lu et al. in Ref. [19] experimentally investigated two adsorption chillers using silica gel/LiCl-methanol and silica gel–water as working pairs achieving a cooling capacity in the range 2.9–5.7 kW with a COP (Coefficient Of Performance) of 0.24–0.41.

Experimental analysis of an adsorption refrigerator with mass and heat-pipe heat recovery process is carried out in [20] achieving a COP of 0.23.

Download English Version:

https://daneshyari.com/en/article/7047703

Download Persian Version:

https://daneshyari.com/article/7047703

Daneshyari.com