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ScienceDirect

Energy Procedia 82 (2015) 623 – 629

Energy Procedia

ATI 2015 - 70th Conference of the ATI Engineering Association

Solar Assisted Ground Source Heat Pump in Cold Climates

Giuseppe Emmi[a], Angelo Zarrella[a]*, Michele De Carli[a], Antonio Galgaro[b]

[a] *Department of Industrial Engineering - Applied Physics Section, University of Padova, Via Venezia 1, Padova 35131, Italy*
[b] *Department of Geoscience, University of Padova, Via Gradenigo 6, Padova 35131, Italy*

Abstract

The geothermal heat pump(or ground source heat pump) uses the ground as heat source or sink for heating and cooling respectively. The design of the borehole field is the key element of these systems since the wrong evaluation of the boreholes' length affects the initial costs and/or the energy performance of the heat pump. The geothermal heat pumps are considered as renewable energy technologies, consequently can help the community to reduce the primary energy uses and also the CO_2 emissions. However the sustainability and efficiency are ensured in the long period only when the heat balance through the ground is guaranteed.

This work evaluates the thermal behavior of ground source heat pumps in cold climates, where the thermal load profile of buildings is not balanced between heating and cooling, especially in residential sector characterized by low internal loads. In these contexts, the heat pump mainly works in heating mode, extracting continuously heat from the ground. As a result, the ground temperature decreases gradually during the years affecting the energy performance of the heat pump. A possible solution to this problem is to use solar thermal collectors to stabilize or gradually increase the mean ground temperature(these systems are called Solar Assisted Ground Source Heat Pump – SAGSHP).

In this work a multi floors residential building with 12 flats (88 m^2 each)is analyzed in three climate zones, making use of the simulation tool TRNSYS. Different configurations of the plant system have been investigated and the case without the solar thermal collectors has been considered as reference.

*Keywords:*borehole heat exchangers, heat pump, solar thermal systems, cold climates, SAGSHP

* Corresponding author. Tel.: +39 049 827 6871; fax: +39 049 827 6896.
E-mail angelo.zarrella@unipd.it

doi:10.1016/j.egypro.2015.12.010

1. Introduction

The massive use of fossil fuels during the last decades has pushed to the exploitation of renewable energy sources also to reduce the CO_2 emissions at the same time. The recently concept of nearly Zero-Energy Building (nZEB) introduced by the recast of the Energy Performance Building Directive (EPBD) [1] combined with the 20-20-20 objective [2] represent an important challenge for the reduction of energy consumption, particularly for construction sector that covers about 40% of the total energy use. Nowadays one of the toughest issues is the improvement of storage efficiency in long time period, especially when renewable energy sources have to be preserved. In this field the most widespread renewable technologies from small to large scale are in the solar field. Ground Source Heat Pump (GSHP) technology has been long discussed in the last years due to its higher performance in Heating, Ventilation and Air Conditioning(HVAC) applications, compared to Air Source Heat Pump systems (ASHPs) [3]. GSHP system is a promising technology able to use the ground as a free heat source and sink for energy storage [4]. The temperature of the heat source-sink affects the efficiency of the heat pump. In ASHPs, the ambient temperature is very variable throughout the year depending on the location's weather and consequently the energy efficiency is also variable over time [5]; furthermore, the defrosting process has to be considered [6]. The use of the ground allows to obtain a more stable performance of the heat pump because the temperature of the ground is affected by the air temperature fluctuation only in the first meters below the surface [7]. Borehole Heat Exchanger (BHE) is the core of the system; it consists of a closed pipe loop buried in the ground and it may be horizontally or vertically oriented[8]. GSHPs work properly when the heating and cooling demand of the building is similar. When the building load profile is not balanced, the mean ground temperature changes during the years of operation. This phenomenon is known as "thermal drift" and its main consequence is the reduction of heat pump's performance. The possibility to use solar energy to recharge the ground in cold climates is one opportunity to use GSHP in heating dominated buildings. GSHPs that use solar thermal energy are commonly defined and known as Solar Assisted Ground Source Heat Pump systems (SAGSHPs) [9] [10].

2. Methodology

Energy analysis of HVAC systems using simulation tools requires consistent information regarding the characteristics of the building, the thermal plant system, and its equipment. In this work the simulation tool TRNSYS has been used. Simulations have been carried out in three locations using the Test Reference Year (TRY) data files [11]: Bolzano (Italy), Stockholm (Sweden) and Montreal (Canada). In the first step the thermal load profiles of the building have been calculated. Afterwards, the heating plant system has been designed and the properties of components of the system have been defined. The conceptual scheme of the system is shown in Figure 1. The main components are: BHEs field, solar thermal collectors field, tank, heat exchanger and heat pump.

In the last part of the study the performance of different layouts of the BHEs field is analyzed. The "baseline" reference case is the configuration without solar thermal collectors field. The design of thethermal plant system has been carried out by choosing the solar collector area, the tank volume and the properties of the BHEs field. The borehole field has been designed according to the ASHRAE method [12]. The maximum solar collectors area is supposed to be installed on south-facing roof side, and the configuration is the same for all the simulations of the location. The tank has a dimension to ensure an easy installation. The BHE characteristics are equal in all the case studies.