ENERGY CASE STUDIES ON A HEAT-PUMP SYSTEM FOR A NON-RESIDENTIAL BUILDING

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This paper focuses on the annual energy consumption of a heat pump system implemented in a non-residential building. This energy consumption takes into account the heating and cooling needs of the building along different periods of time, such as winter and summer. Moreover, for each year period, we compared the heat pump efficiency simulated for three different weather zones (1,2 and 3) according to the Romanian standard SR 1907/1-1997. The heat pump used for these studies is a borehole heat exchanger, coupled with a low temperature heating floor (radiant floor).

Keywords: heat pump, geothermic, radiant floor, building.

1. Introduction

The research and development on geothermal systems is very complex because most of this technology is being used in many economic fields and therefore it will contribute to a large area of applicability. From this point of view, the research includes the enhancement of deep resources extraction, the production of special materials used for high temperature and pressure; and geothermal heat pumps development. Many European Union (EU) countries, such as: France, Germany, Great Britain and the Czech Republic are concentrating on enhancing the research on geothermal systems (GS). Their main research goal is the creation of a map of the most profitable exploitation zones for GS, the enhancement of thermal evolution tracking of the existent drilling spots and real-time measurements.

The main obstacle in geothermal exploitation is the drilling cost [1]. Geothermal power plants are, traditionally, built on the edge of the tectonic plates, where high temperature geothermal resources are closer to the surface [2]. Most of the geothermal technology uses the underground water network which is not available everywhere. Partially for these reasons the drilling exploitation success rate can be pretty low, around 20%, and not more than 60%. The other two important difficulties are the complex licensing system and the lack of coherent

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legislation, especially referring to the property rights over the geothermal resources.

The possibility of large scale utilization of geothermal energy will need education and advertising campaigns for everyone and also an accentuated raise in the R & D of geothermic systems, with the purpose of minimizing the impact of the geothermal resources exploitation on the environment. There is also the need of future research regarding emerging concepts such as: enhanced geothermal systems or hybrid systems and cascading use of these systems [3]. International collaboration, based on research and centralization of existing knowledge and data relating to geothermal energy and connections, from both inside and outside the EU, will be extremely important for the development of the geothermal sector. In order to ensure adequate manpower for this sector there are certain needs like special training and adequate certification.

Under a worldwide scale, since year 2005, 72 countries have started to use geothermal energy resources for various applications [4]. The total installed capacity was about 28270 MWt, and the energy consumption was about 273372 TJ/year or 75.940 GWh/year. In 2005 more than 50% of the total geothermal supply was achieved by geothermal heat pumps. The installed capacity has doubled almost every 5 years since 1995 and the energy consumption has raised by a 2,5 factor. The use of geothermal supply in 2005 yielded an annual saving of 25.4 Mt of fossil fuel and a 24 Mt CO2 emission reduction.

The energy analysis of a coupled system of type: ”geothermal heat pump-building” represents an interesting challenge for HVAC engineers, as well as for building owners, because of important energy savings resulting from the use of such a system. The main purpose of this paper is to outline some important factors influencing the energy consumption and the coefficient of performance (COP) for a “building-geothermal heat pump system”.

The analysis of the system commissioning was made using a numerical model developed within TRNSYS software and validated with experimental data acquired on a real building-the Laboratory of the Building Services and Equipment Faculty. Thus, we obtained a series of useful information on the heat pump efficiency, which can be extrapolated to other types of buildings and in different weather conditions and usage, enabling the establishment of criteria for assessing the implementation of such a system.

2. Methods and validation

In Fig.1 is outlined the experimental set-up on which the heat pump measurements were realized, actually a complex installation which has as a main element the geothermal heat pump. The experimental station is represented by a heating/cooling installation which uses a water/water heat pump. There is also a solar panel installation connected to the heating storage tank.

On the functional scheme depicted in fig.1 it could be observed the main component elements of the investigated installation. These elements are the following:

- Geothermal heat pump composed of : a water to water plate heat exchanger, connected on one side to the thermal captors buried under the ground, and on the other side to the heating/cooling circuit supplying the heating/cooling radiant floor.
- Storage tank;
- Solar panel;
- Hot water station;
- Temperature sensor system;
- Three-way valves, one of them is used to recycle the thermal agent through the floor-heating circuit ;
- Circulation pumps, two of them being integrated in the heat pump unit.

The hot/cold reservoir of the geothermal heat pump is the ground: 8 captors buried into the ground grouped 2 by 2, at depths varying from 80 to 120 m. The fluid circulating between the heat pump and the captors is a water-glycol mix, in order to avoid the frost risk occurring during the cold season.

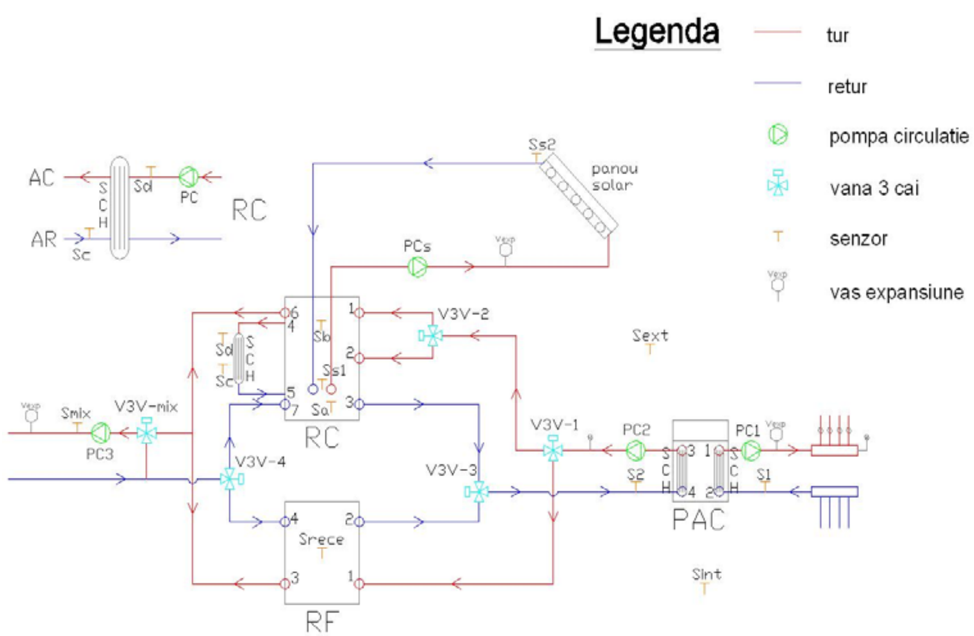

Fig. 1. Overview of the experimental set-up of the heat pump

In order to reach experimental data with great degree of accuracy, we choose high-precision instruments, their functionality being studied with great care.

In order to determine the weather factors that influence the energy and humidity transfer through the building envelope, a mobile weather station was used, this station belonging to Building Services Laboratory (Fig.2.). In this study, the tracked parameters were the following: temperature, relative humidity of the external air, diffuse and total solar radiation; the measurements were done with a 10 min time-step.

In order to determine the fluids temperature within the system, special temperature sensors were used, and for the fluid flow special ultrasound flow meters were used, mounted directly on the pipes.

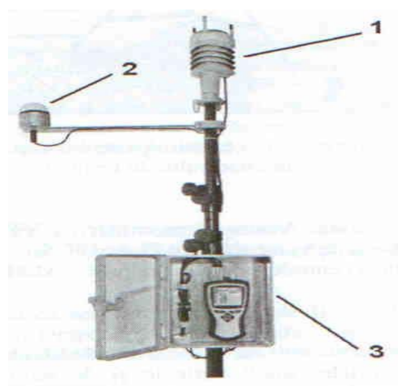

Fig. 2. Weather station used during experimental data acquisition

The "heat pump-building" computer model

The numeric simulation of the heat pump system operation is highly important in order to find a solution to reduce the energy consumption within the building. With the help of the TRNSYS simulation software [5], a numerical model was built-up for the heat pump system connected to a building. This model represents a starting point for the evaluation of the heat pump system under different conditions, in order to implement these systems in various types of buildings.

The model created, which also includes all the systems components and connections between them (fig.3) represents the starting point of future research in order to find solutions for implementing this system in a building. Through TRNSYS simulation, all the parameters which describe the operation of the heat pump system have been individually evaluated offering the possibility to observe the influence of each one upon the system operation. Some of the simulations results performed with this model have been compared to experimental data collected from the real installation. The automation in the TRNSYS model has been detailed especially that it shows the importance of it when the system is running.

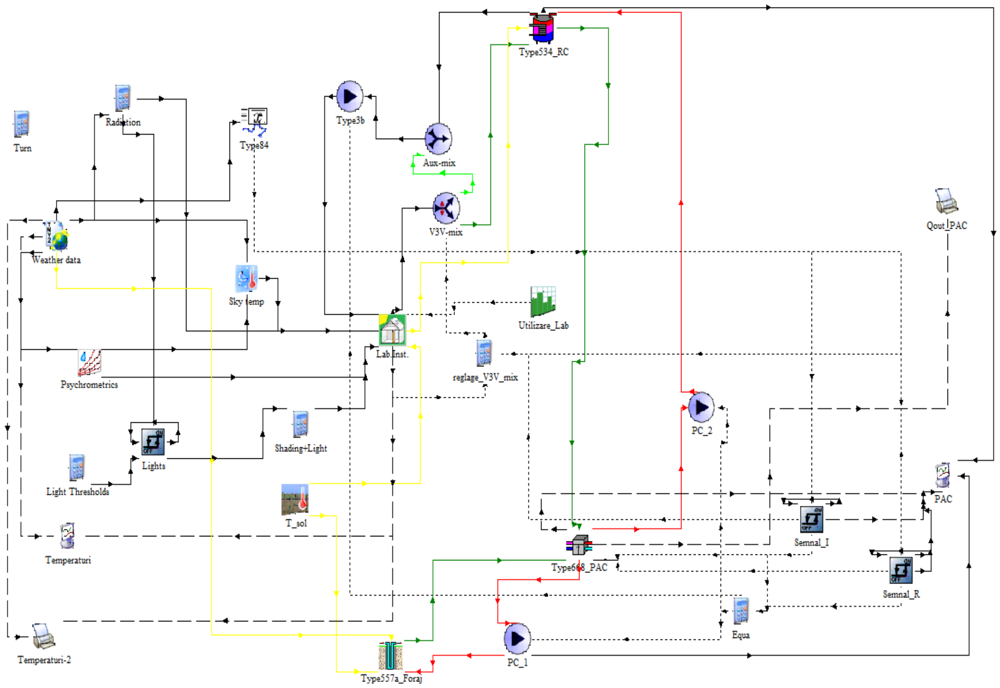

Fig. 3. TRNSYS model for the “heat pump-building” system

The validation of the computer model has been realized by comparing the experimental results with those calculated with the TRNSYS model. These results refer to two critical parameters: interior air temperature and the heating/cooling floor temperature, in accordance with the need of cold/ heat from the analyzed building.

The input data from the computer model were meteorological data (exterior air temperature and solar radiation) and the building thermal characteristics.

One of the measurement sets were done on May 21st between 6.30-12.30 in order to evaluate the heat pump system under the heating regime (Fig.4)-considering $t_{i,min}$=20 C, and the other measurements sets were performed on June 5th between 11.30-16.30, for the evaluation of the cooling regime of the heat pump- considering $t_{i,max}$=26 C (fig.5).

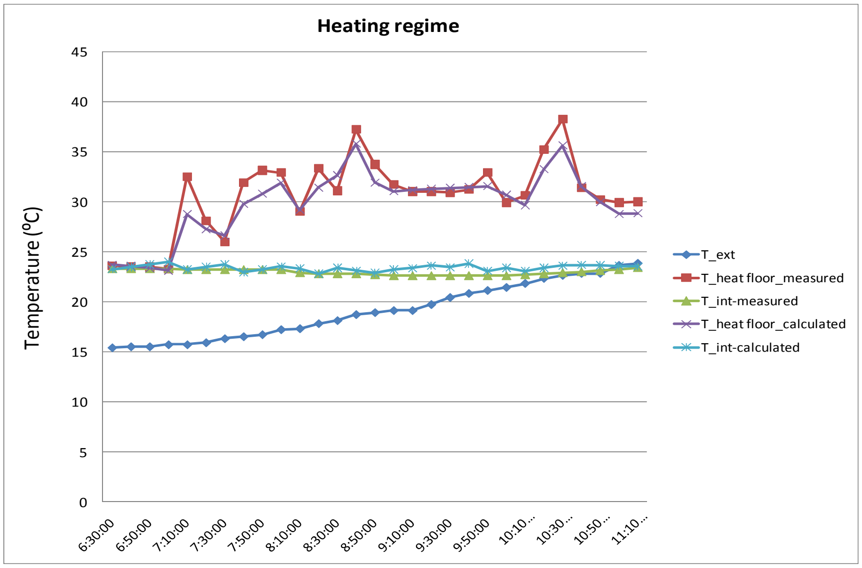

Fig. 4. Comparison between numerical and experimental data for the heating regime

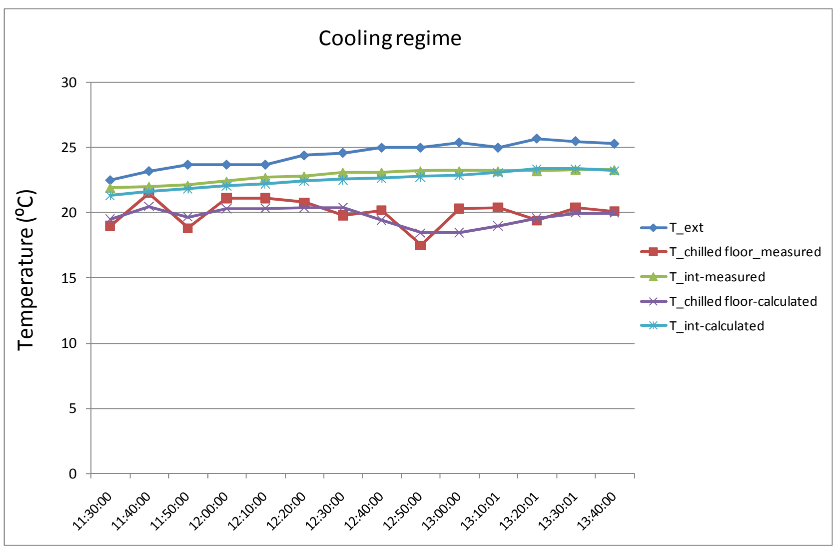

Fig. 5. Comparison between numerical and experimental data for the cooling regime

3. Case study

The following case study shows the influence of the climatic zone in which the building is situated upon the energy consumption of the heat pump and of course upon the performance coefficient (COP) of the "heat pump-building" system.

The analyzed period chosen for the case study is January, the coldest month of the year. In this way it was easier to observe the way the heat pump system responds to the thermal requirements. Because there was no hourly Romanian weather database, we used weather data collected from the TRNSYS database for three Romanian cities belonging to three different climatic zones. These cities were: Constanta-for the climatic zone 1, Bucharest-for the climatic zone 2 and Iaşi- for the climatic zone 3.

The building used in these simulations had a low thermal inertia. The internal temperature was supposed to be maintained at 20°C by the contribution of an auxiliary heating system (boiler) having a global efficiency η=90%.

The temperature variation of the heating floor (Fig. 6), in the TRNSYS simulation, is correlated with the exterior temperature variation. The difference observed between the three climate zones is due to the indirect influence the exterior air temperature has upon the floor. That way the floor temperature depends on the interior air temperature which varies according to the heat-loss through the buildings envelope. These heat losses depend on the variation of the external air temperature and the thermal characteristics of the envelope. There can be seen a small time delay between the peaks of the external air temperature and the peaks of the floor temperature.

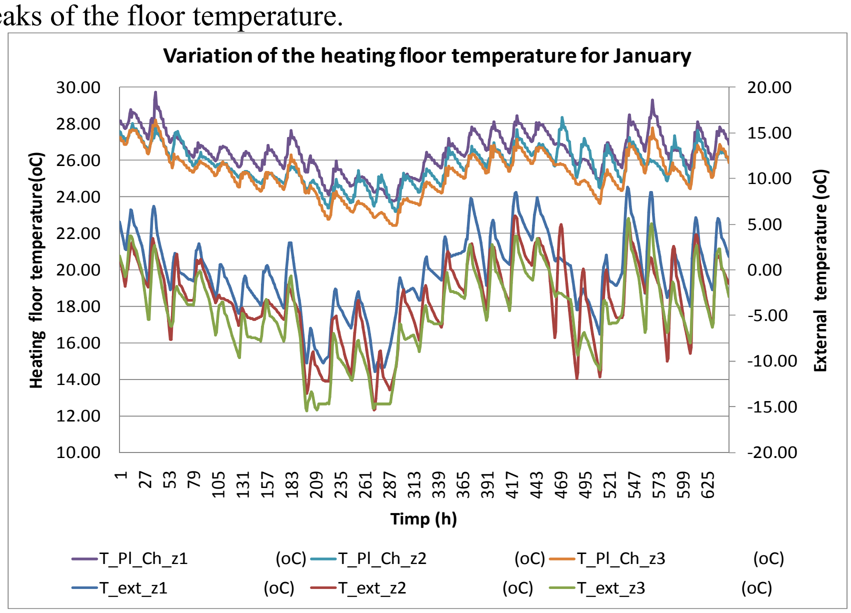

Fig. 6. Variation of the heating floor temperature for January

The performance coefficient variations (COP) of the whole system (Fig.7), for all the three cities are similar, though existing small differences between the 3 variation curves. This is due to the influence of two essential factors: external air temperature and the thermal characteristics of the envelope.

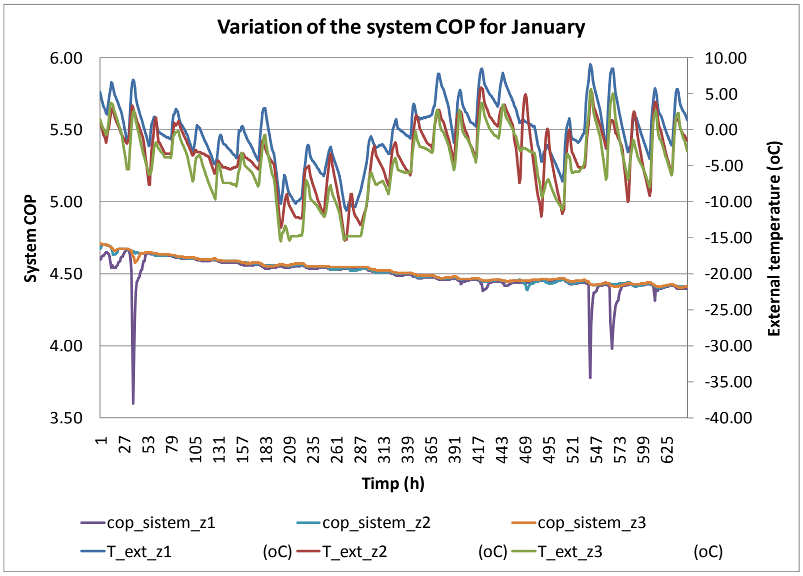

Fig.7. Variation of the system COP for January, for three climatic zones

4. Conclusions

This study outlines the thermal behavior of a geothermal heat pump connected to a building having low thermal inertia. The experimental data collected from the heat-pump system showed a good agreement with data obtained by numerical simulation using TRNSYS. A case study applied to the same configuration showed some influence of the weather data on the heating floor temperature, as well as on the system COP. However, the differences in terms of global COP are quite small, due to the building low thermal inertia.

More research work is to be done for this type of systems in order to outline other influence factors having a greater impact on the electrical consumption of the heat pump.

R E F E R E N C E S

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