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Two years of recorded data for a multisource heat pump system: A performance analysis

F. Busato, R.M. Lazzarin, M. Noro*

Department of Management and Engineering, University of Padova, Str.lla S.Nicola 3, Vicenza (VI) 36100, Italy

HIGHLIGHTS

- We monitored an HVAC plant based on multisource heat pump for two years.
- The electricity consumptions of auxiliaries (pumps etc) were taken into account.
- A detailed first law energy balance of the plant was calculated on a monthly base, as well as a Primary Energy balance.
- The use of more than one heat source at the evaporator level increases the efficiency of the heat pumps.

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ABSTRACT

The concept of a low energy building in a temperate climate (according to the Koppen climate classification) is based upon the following principles: reduction of heat losses through enhanced insulation; the inclusion of heat recovery on mechanical ventilation; and the use of high efficiency heating/cooling systems integrated with renewable technologies. It is almost impossible to achieve optimum results in terms of global energy efficiency if one of these elements is omitted from the design.

In 2009, a new school building, integrating these three key elements, was opened in Agordo town, located in northern Italy. The main design features of the building incorporate a well insulated envelope and a space heating and ventilation system driven by an innovative multisource heat pump system.

Outdoor air is a common heat source, although it does have widely documented limitations. Heat pump systems can utilise more efficient sources than air, including those of ground heat, solar heat, and heat recovery. The installed system within the school building incorporates these three sources. A multisource system aims to enhance the performance of the heat pump, both in terms of heating capacity and overall efficiency.

The present work includes evaluation and analysis of data obtained through real time monitoring of the working system in operation, for a period of approximately two heating seasons. During this time, the behaviour of the system was assessed and the incorrect settings of the plant were identified and subsequently adjusted as required. The energy balance indicates that the integration of different sources not only increases the thermal performance of the system as a whole, but also optimizes the use of each source. Further savings can be obtained through correct adjustment of the set point of the indoor temperature.

During the final stage of the study, the total energy consumption of the new building is calculated and compared to that of the former building that housed the same school, which had similar dimensions.

1. Introduction

There are many ways to reduce the energy needs and heating/cooling capacity of a building. In a temperate climate (as defined by the Koppen [1] climate classification), the following options are considered to be appropriate:

- to design a low energy building envelope with good thermal insulation;
- to choose energy effective technologies based on a high efficiency generation system, such as heat pumps;
- to integrate design and systems with heat recovery devices and renewable energy sources wherever possible.

* Corresponding author. Tel.: +39 0444 998704; fax: +39 0444 998884.
E-mail addresses: busato@gest.unipd.it (F. Busato), renato@gest.unipd.it (R.M. Lazzarin), marco.noro@unipd.it (M. Noro).

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Nomenclature

a_1	solar collector heat loss coefficient
AHU	air handling unit
CP	central heating plant
E	energy
EP	specific primary energy demand for heating
GUE	gas utilization efficiency
HDH	heating degree hours
HHV	higher heating value
HP	heat pump
HVAC	heating, ventilation, air conditioning
I	solar radiation
LHV	lower heating value
P	power
PER	primary energy ratio
T	temperature

Subscripts

CA	condenser-absorber
E	evaporator
G	generator
el	electricity
gnd	ground
in	input
m	mean-average
n	nominal
min	minimum
oa	outdoor air
p	peak
sh	space heating
T	threshold
th	thermal
vent	ventilation

Greek

η	efficiency of solar system
η_0	zero loss solar collector efficiency
β	solar system tilt angle

These three features have been incorporated into the new High School Building of Agordo, situated in the province of Belluno, northern Italy. This building was designed in 2006–07, and was occupied in autumn 2009. It is operated by the Belluno Province Administration, an organisation appointed by the public education service.

The town of Agordo lies in a valley at 611 m above sea level, in the geographical area of the Dolomiti Mountains, where the climate is severe during wintertime (3376 degree-days). In terms of dimensions, the building has a total floor area of 5680 m^2, an outward surface area of 13,608 m^2, and an enclosed gross heated volume of 19,644 m^3. The envelope is well insulated, with the outer walls and the roof allowing for an average thermal transmittance of approximately 0.16 W/(m^2 K), the floor having a thermal transmittance to the ground [2] of 0.4 W/(m^2 K), and the glazing system having a thermal transmission of 1.38 W/(m^2 K).

From an architectural and functional point of view, the building comprises of two main wings and a central belt, as it can be seen in Fig. 1. The south-east wing has three storeys and houses teaching rooms, used mainly (but not solely) in the morning. The west wing has two storeys and houses the laboratories, used mainly (but not only) in the afternoon. Finally, the three storeys of the central belt house the administrative offices which are occupied constantly throughout each day, and the auditorium, which is used occasionally.

The school is closed from the middle of June to the beginning of September. The climate management system therefore provides ventilation and space heating, but there is no requirement for summer cooling.

Through dynamic simulation using the TRNSYS environment, different solutions were evaluated with respect to the heating system [3,4]. A multisource gas-fired absorption heat pump system has been designed to fulfil the needs of the building, utilising ground and solar energy, with recovery on ventilation. The heat pumps selected are Robur GAHP-W-LB type. A full system evaluation was undertaken at the design stage, in order to select the most viable mixed solution, and to optimize the size of both the borehole ground exchanger field, and also the solar system [5].

The efficiency of the absorption heat pump is called *GUE* (Gas Utilization Efficiency), that is the ratio between the useful thermal output E_{CA} and the thermal input E_{in}; usually this figure is around 1.2–1.5. The efficiency of a compression heat pump is called *COP* (Coefficient of Performance), that is the ratio between useful thermal output E_C and the electricity input E_{el}; usually this figure is around 3–4. From the First Law of Thermodynamics, the heat amount coming from the heat source is the difference between the output and the input (whatever thermal or electric). So in heating mode, the ratio between the thermal input from the heat source and the thermal output to the heat sink is much lower for an absorption heat pump (around 0.2–0.3) than for a compression pump (around 0.6–0.8). The latter would therefore require a larger, and consequently more expensive, borehole field.

2. Description of the HVAC plant

The HVAC system in teaching rooms, laboratories and offices provides space heating by means of radiant under floor installation, in addition to ventilation. It utilises three independent AHU, each of which serves a single-duct [6] system. The auditorium is supplied by an all-air system. Design calculations, performed according to the UNI EN 12831:2006 standard, showed that the space heating requires a maximum power of 146 kW and the ventilation system

Fig. 1. Photo of the building (view from south).