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Energy study in water loop heat pump systems for office buildings in the Iberian Peninsula

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Abstract

The energy consumption is analyzed for the air conditioning of an office building in four important cities of the Iberian Peninsula. A water loop heat pump (WLHP) system is compared with a conventional water system. Energy redistribution is an important advantage, but significant savings come from heat pumps high efficiency parameters and minor air flow rates in the cooling tower. Even using natural gas as energy source, 8.1% decrease of CO_2 emissions is reached, but additional important reduction can be easily obtained by using a solar thermal energy system as energy source.

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Keywords: Water loop heat pump; heating ventilating and air conditioning; office building energy consumption.

1. Introduction

Water loop heat pumps (WLHP) systems are usual in air conditioning of commercial and office buildings. In this scheme one water loop circuit receives energy from the condensation and yields it to the evaporation of reversible heat pumps that attend thermal loads of different zones of the building. The net necessary energy to keep the water loop temperature in a range can be obtained from gas boilers or other energy production systems and dissipated by cooling towers. One important advantage of these systems is the transfer of energy between zones of the building when serving

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loads of opposite sign. Besides, heat pumps using the water loop as a source, work with very good efficiencies, EER in refrigeration or COP in heating mode.

Some references to WLHP systems can be found in specialized literature. Their performance has been analyzed in representative weathers in China [1] and in several European climatic areas [2]. Yuan and Grabon [3] optimized their working parameters by mathematical modelization.

The present study analyzes the behavior of a WLHP system in a common office building under climatic conditions of four important cities in the Iberian Peninsula. Energy consumptions of this system and other more conventional system are compared. It is a water system with four tube connection design to allow simultaneous heating and cooling loads, fan-coils, gas boiler and a conventional chiller. The objective is to obtain important information that can be useful to reduce energy consumption in WLHP systems for HVAC.

2. Calculation of energy demands and systems energy consumptions

2.1. Energy demand in an office building

A regular office building was studied to obtain the detailed energy demand profiles corresponding to four representative cities. The building has three occupied plants, as well as not habitable attic and ground floor zones. Total inhabited gross area is 918 m^2, and it has external zones with four orientations and an inner zone, as shown in Fig. 1 (a) and (b).

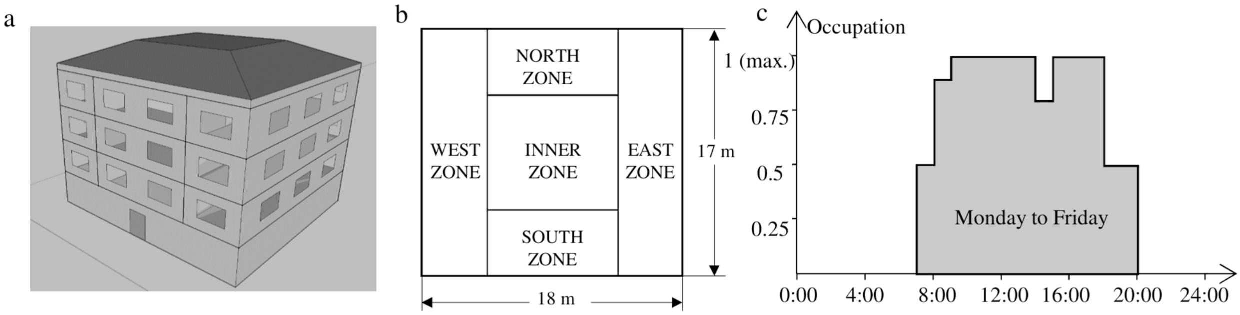

Fig. 1. (a) External view of the building; (b) distribution of thermal zones in the occupied plants; (c) office occupation profile.

Typical compositions were chosen for the opaque surfaces, resulting in 0.517 W/m^2-K U-factor values for walls and 0.563 W/m^2-K for floors and ceilings. U-factor for windows is 2.9 W/m^2-K and its solar heat gain coefficient is 0.72. Internal heat gains were included for people, lighting and office equipment: people activity was estimated in 130 W/p, with an occupation density of 12 m^2/p; the heat gain from lighting was fixed in 7 W/m^2 and 8 W/m^2 internal heat gain for the office electric equipment. The ventilation air volume was fixed in 12 l/s-p. These are maximum values for people, lighting, equipment and ventilation loads. Their profile follow the occupation schedule in Fig. 1 (c). Constant air infiltration values were fixed for not habitable zones: 2 air changes per hour in the attic and 3 changes per hour in the ground floor. The loads were calculated in ideal air loads mode, with cooling and heating thermostat schedules that keep air temperature in a range between 21 and 25ºC in working hours, from Monday to Friday, and humidity controls to keep humidity ratios between 45 and 55% in the same schedule.

Calculations were performed with the EnergyPlus [4] simulation software, using the OpenStudio(R) [5] platform to define the building, loads and weather data. The energy demand was calculated for climatic conditions of four cities in the Iberian Peninsula: Madrid, Barcelona, Zaragoza and Porto. The weather data files were obtained from the EnergyPlus site, choosing weather data from the SWEC (Spanish Weather for Energy Calculations) database for Spanish cities and from the IWEC (International Weather for Energy Calculations) for the Porto weather data.