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Solar assisted heat pump with ice storage for a 19'000 m^2 retrofitted multi-family building complex

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Abstract

This paper concerns the evaluation of a 500 kW solar assisted heat pump system with combined ice storage installed on "La Cigale", a 19'000 m^2 retrofitted multi-family building complex situated in Geneva. The presented results are based on a detailed monitoring campaign, covering a full year of operation, in real use conditions. After presenting the system concept, the system performance is analyzed by way of a detailed Sankey diagram (heat and electricity flows between the various production units, heat storages, and demand units), along with specific analysis of the diverse sub-systems. As a complement to the monitoring results, we present a simulation tool that was specifically developed for this type of application, and its validation against monitoring data, in terms of annual values and monthly profiles of the diverse energy flows.

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Keywords: Solar thermal, Heat pump, Monitoring, Simulation

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Nomenclature

COP	coefficient of performance (hourly value)
DHW	domestic hot water
HP	heat pump
SH	space heating
SPF	seasonal performance factor (annual value)

1. Introduction

Located in Geneva, the cooperative housing complex “La Cigale” (2 building blocks, 13 alleys, 273 apartments, 458 residents) was built in 1952 and has a total energy reference area of 19'000 m^2. The oil consumption of these buildings amounted to approximately 150 kWh/m^2 per year for space heating (SH) and domestic hot water (DHW) production. Between 2013 and 2014, the buildings were renovated in accordance with the Minergie-P standard; this action was the most important operation of this type in Switzerland.

The extensive renovation of the building envelope was performed on an occupied site and required the following: i) use of prefabricated façade and roof elements allowing to achieve quality exterior insulation within short intervention periods; ii) the transformation of balconies into loggias : this helps limit thermal bridges, favor passive solar gains and provide a buffer space that can be used in different seasons; iii) the installation of heat recovery on the ventilation system of each alley.

The heat production is mainly provided by a solar roof (unglazed solar collectors covering the south-east and south-west facing roof areas) coupled with a series of heat pumps (HP) using a latent heat storage (water/ice) [1].

2. Heat production system

2.1. Components

The building complex has two heat production systems (one for each block, Vermont and Vidollet). Both systems are composed of brine-water HPs (Vermont + Vidollet : 200 + 300 = 500 kW, at B0W35), whose evaporators are connected to a field of selective unglazed solar collectors (650 + 1090 = 1740 m^2) and an ice storage (30 + 30 = 60 m^3). As an alternative, the solar roof also allows providing direct solar heat (without using the heat pump). In addition, a back-up gas boiler (130 + 200 = 330 kW) ensures a 100% availability of DHW and heating.

All the components are connected to a 4-temperature hydraulic bus that allows heat exchange between the heat producers and heat consumers (SH, DHW). A stratified storage tank (12 + 20 = 32 m^3) is connected to the extremity of the bus allowing heat storage for DHW production in the upper part, whereas the middle part serves as a buffer for the HP and the bottom part is devoted to storing low temperature solar energy.

2.2. Operating principles

The operating principles of the system are the following (Fig. 1):

- During summer, the uncovered selective collectors provide direct solar heat (without using the HP) for the production of the DHW.
- In midseason, the solar roof is used in priority to regenerate the ice/water storage, i.e. melting of the ice and subsequent heating of the water up to 18°C (highest admissible temperature for the HP). Once this objective is reached, the solar roof is used for direct solar heat production. The HP provides the complementary heat by extracting the energy contained in the ice storage (which cools from 18°C down to 0°C, where the water freezes again).
- At night or in the absence of sunlight, the HP ensures the production of SH and DHW by extracting the energy contained in the ice storage. If the weather conditions and temperatures permit, the solar roof is used as an exchanger on ambient heat and for regenerating the ice storage.