Case Study summary

IEA-ECBCS Annex 48

Heat Pumping and Reversible Air Conditioning

Italy Case Study N°4: Multi-purpose heat pumps for simultaneous heating and cooling

150 anni di Cultura Politecnica

Contribution of Politecnico di Torino

Introduction

The Santa Giulia district comprises 5 buildings and is located in the South part of Milano, where the aquifer is very close to the ground surface. The overall treated area comprises approximately 4,500 m^2 of offices, showrooms, restaurants, meeting rooms. The data collected on-site concern a unit serving an area of approximately 1,500 m^2; a further two multi-purpose units and two reversible heat pumps serve the other 4 buildings in the Santa Giulia complex.

Summary

- Location: Milano, Italy
- Building sector: Office, Restaurants, Showrooms
- Gross net area: 1.500 m^2
- Heat pump cooling capacity (cooling mode): 261 kW
- Heat pump heating capacity (heating mode): 300 kW
- Heat pump cooling capacity (cool+heat mode): 209 kW
- Heat pump heating capacity (cool+heat mode): 292 kW

International Energy Agency

ECBCS

Background

The multi-purpose units, units for 4-pipes systems, are electrically powered heat pumps able to satisfy simultaneously opposite loads with the highest global efficiency as possible. The operating principle is based on the idea to remove heat from the ambient to cool to transfer it to the ambience to heat. These units, therefore, are a valid alternative to the traditional combination of a chiller with a boiler in 4-pipes plants, as they save both running and installation costs. The case study analyzes power consumption during 2007 of a groundwater source multi-purpose unit installed in a multifunctional building in Milan (Italy). The consumption of the installed solution is compared with those calculated for a chiller and a boiler hypothetically being installed and operating for to satisfy the same building's loads.

Technical data of the system:

Multi-purpose unit, heating+cooling mode:

- Cooling power: 209 kW
- Heating power: 290 kW
- CEU: 6.04
- Evaporator in/out T 11/7°C
- Condenser in/out T 40/45°C

General concepts

The operating logic of multi-purpose units is extremely simple: in buildings characterized by opposite thermal loads, be able to exploit on demand both the heat exchanges required by the refrigerant cycle. The system has an open circuit, with direct use of ground water. It adopts a simple but effective solution which noticeably limits the use of underground water: the tank of the fire-fighting system is used as a large inertial storage tank; a dedicated sensor constantly controls its temperature and if this falls outside an optimal range the tank is drained and then re-filled with fresh water from the well, thus restoring optimal conditions. The system comprises 2 wells (at an approximately constant temperature of 15 °C throughout the year, at an average depth of 10-12 m) from which water at 30 L/s is pumped to a storage tank.

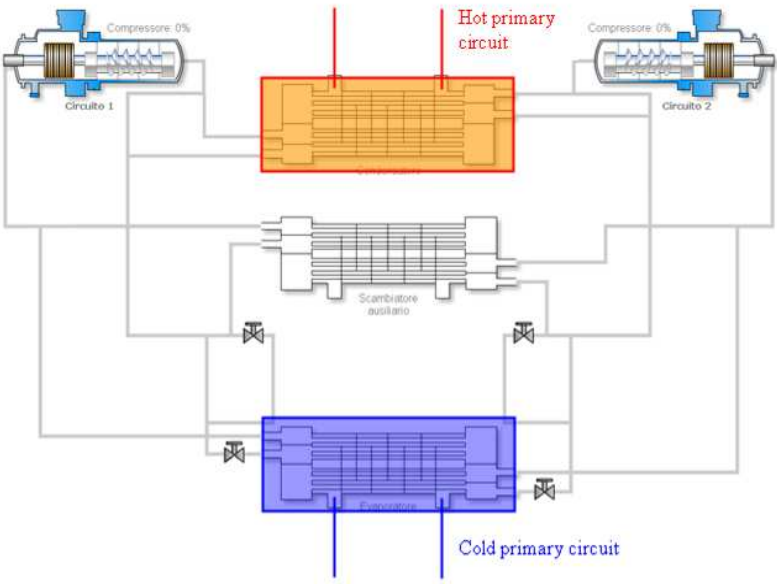
Multi-purpose unit

Advantages

- High efficiency in building characterized by opposite thermal loads
- A single unit could replace a conventional HVAC system (boiler + chiller)
- Stable COP/CEU due to underground water condensing

Drawbacks

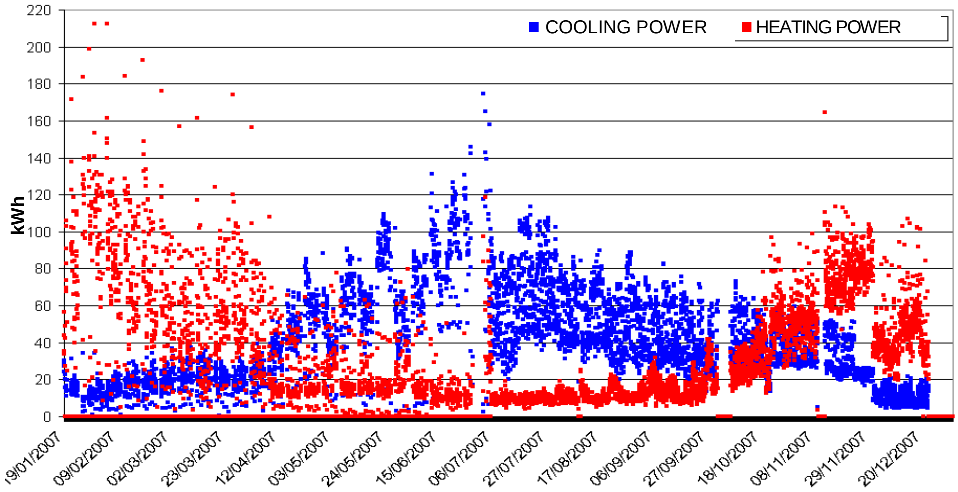
- Application limited to building with contemporary opposite thermal loads



System lay-out

Data monitoring

In the graph are shown heating and cooling energy provided by the multi-purpose unit as measured with the energy metering system during 2007 (starting on 19th January). It can be reasonably assumed that the energy delivered by the unit is exactly that requested by the building in order to guarantee the internal comfort; on this assumption, the graph represents the load profile of the building.

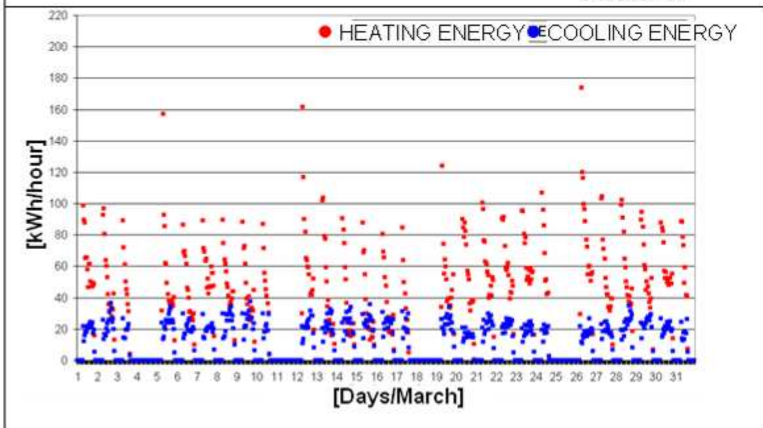


Heating and cooling energy given during 2007(hourly sampling rate)

Simultaneous factor and REP

Data have been analysed month per month in order to understand when the unit was working, the utilization's rate and the 'average simultaneousness factor'. The report for the month of march is shown. This parameter can be seen as a simple way of estimating the amount of time in an hour the unit works with a "dual effect", that is, producing a useful effect both in the heat exchanger hydraulically connected to the hot and cold primary circuit of the plant. REP (Ratio of Primary Energy) was defined to allow primary energy comparison between multi-purpose unit and standard solution. Mathematical basis of REP is shown at the end of the page.

MARCH



Total hours 01/03/2007 - 31/03/2007: 744
N° of hours with unit ON: 379
5 Days/week (Mon-Fri)
7.00 - 22.00
1 Day/week (Sat)
7.00 - 16.00
N° of hours with simultaneous demand: 375
Maximum cooling demand [kW]
37,4
Maximum heating demand [kW]
174,0
Average simultaneousness factor: 47%

Thermal load report, month of march

$$REP_{multi-purpose} = \frac{E_{\sup plied}}{E_{primary.input}} = \frac{E_{\sup plied}}{E_{electrical.input} / \eta_{SEN}} = \eta_{multi-purpose} . \eta_{SEN}$$

$$REP_{chiller+boiler} = \frac{E_{\sup plied}}{E_{primary.input}} = \frac{E_{\sup plied}}{E_{electrical.input.chiller} / \eta_{SEN} + E_{heat.boiler} / \eta_{boiler}}$$

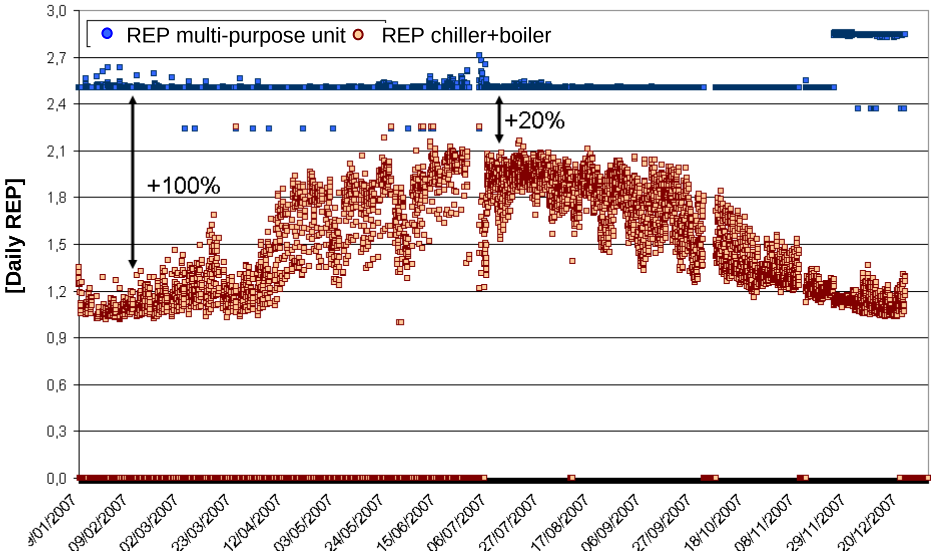
Formula definitions

ηSEN = conversion performance estimate of the Italian electricity system in 2007 = 45.4% (Electricity and Gas Authority, DCO 2/08);

ηmulti-purpose = (according to the state of the machine hour by hour) EER or COP or CUE

Consumption comparison

Given the load profiles of the building, as measured through monitoring, we can now investigate the behaviour of the multi-purpose unit. For the comparison a chiller was chosen with the same characteristics as the multi-purpose unit: heat rejection using ground water, screw compressors and R407C refrigerant. The boiler, instead, is a condensing boiler with a capacity of 300 kW. The REPmulti-purpose is always higher than the REPchiller+boiler and that the latter performs in a more variable way. During winter, for example, the boiler, which has an intrinsically lower REP than that of the electrically-powered machine, consumes more primary energy.



REP for the multi-purpose solution and for the chiller+boiler solution

Conclusion

Data acquired demonstrate that the presence of opposite loads was detected in over 99% of all the working hours of the unit. In this type of building only a multi-purpose unit for 4-pipe systems can address dual demand, among other things, working at much higher efficiency levels compared with any other traditional solution. The log of electric consumption of HVAC system is need to provide a correct optimization of the system. Months of March, April, May, September, October and November are characterised by the favourable balancing of opposite loads (average simultaneousness factor ≥ 40%). This is the situation in which a multi-purpose unit achieves the highest savings with respect to a traditional chiller + boiler system.

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Literature

IEA-ECBCS Annex 48 website: http://www.ecbcs-48.org

Article: E. Busnardo, L. De Rossi, L. Basso, Unit for 4-pipes systems. Energy metering study on a 4-pipes plant of a multi-purpose building, Clima 2010, Antalya 09-12 May 2010.