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In-field monitoring and numerical parametric analysis of a low power adsorption solar cooling plant in Italy

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Abstract. Solar cooling of small buildings represents a very interesting potential market, still underdeveloped and characterized by a wide range of uncertainties, both on the technological and the economical side. Actually, there are a few low size ready-to-market adsorption/absorption chillers and their costs are significantly higher than technically mature compression systems. The combination of solar thermal systems with solar assisted chillers needs a thorough design stage to be correctly optimized and this may turn out unaffordable for a low size project.

In order to evaluate the practical feasibility and shed more light on small size solar assisted cooling systems, a monitoring campaign has been carried on a new building built at the facilities of IPLA[1] in Turin, Italy. The building has a wooden highly insulated envelope, controlled mechanical ventilation with thermodynamic heat recovery, radiant heating/cooling. A solar thermal collector field is integrated in the roof of the building (Fig.1), used both for the building heating and cooling demand, thanks to a 9kW adsorption chiller .

An automatic monitoring system has been installed on the system, and its measurements have been tested with certified portable instruments. Data are available since August 22, 2011.

Fig. 1: Picture of the new building with integrated solar thermal (up) and photovoltaic collectors (bottom)

Dynamic simulations of the system, using software Polysun © for solar cooling plant and Energy plus © for building demand assessment, have also been realized and compared with in-field measurements. The validated model has been used for a parametric evaluation of the effects of the installation of different components and control strategies. Main alternatives evaluated are: vacuum tube collectors, double glazed collectors, different usage of backup boiler (direct backup or storage backup), different set point temperatures and different heat rejection systems.

Key words

Solar cooling, in-field measurements, parametric simulation, solar fraction

[1] IPLA is a public Research Institution dealing with plants, wood and environment

1. Introduction

Solar cooling has been theoretically explored during the ‘80s’ spread out of solar technology, but a very little number of plants have been actually installed and measured so far.

The UE’s “20-20-20” task has brought new attention to thermal exploitation of solar source.

The solar cooling system of PUEEL building at IPLA institute in Turin, Italy, is the first of this kind in the nearly 1-Million inhabitants city, and one of the few of entire Italy.

During the design stage, an adsorption chiller with a low value (60°C) of nominal driving heat temperature has been selected and coupled to water double glazed solar collectors., Due to budget reasons, during the construction phase this type of collector has been replaced with single glazed one

2. In field monitoring

A. Plant scheme

The PUEEL building solar cooling system is based on a simple scheme (Fig.2). The 20m^2 solar collector field supplies heat to a water storage tank of 4m^3. The storage tank is fitted with a thermostatically controlled auxiliary heat source (electrical resistance). A 9kW peak power chiller, based on an adsorption cycle with zeolite is driven by the heat flow coming from the storage tank and refrigerates the building by mean of a radiant panel cooling system. A chilled water storage tank of 0.5m^3 is installed on the cooling circuit. Heat rejection from the chiller is based on a fan driven dry cooler, placed in the nearby of the technical room.

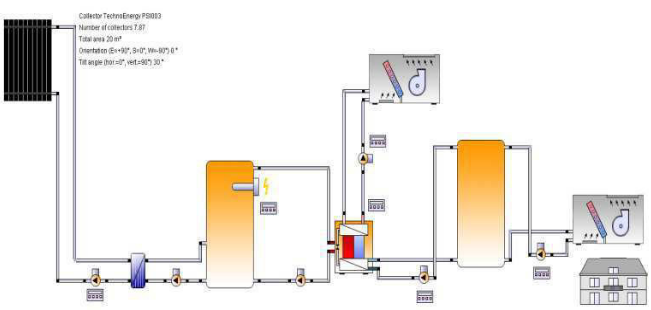

Fig. 2: Polysun 5.3 outlook of the schematics of the plant

B. Monitoring system

A monitoring system has been installed on site. Table I shows analogical entries of the system. Other digital controls and states are present.

The system has remote features, and data can be downloaded and by through a programmable authorized PC by internet connection and a Java based interface.

It should be mentioned that September 2011 has been the warmest September in Turin from 1753, with average (day and night) temperature of 23.1°C and daily peaks around 30°C. The system has worked in cooling mode till the 10th of October.

Table I. – Plant monitored variables

Circuit	Variable	Unit	Precision
Solar loop	Water return temperature	[°C]	±0.5
	Water supply temperature	[°C]	±0.5
	Flow rate	[m^3/h]	±0.01
Driving heat to chiller	Water return temperature	[°C]	±0.5
	Water supply temperature	[°C]	±0.5
	Flow rate	[m^3/h]	±0.01
Radiant panel cooling	Water return temperature	[°C]	±0.5
	Water supply temperature	[°C]	±0.5
	Flow rate	[m^3/h]	±0.01
Heat rejection	Water return temperature	[°C]	±0.5
	Water supply temperature	[°C]	±0.5
	Flow rate	[m^3/h]	±0.01

Table II. – Meteorological monitored variables (hourly samples)

Sun	Global horizontal irradiance
Outdoor air	Air temperature
	Air humidity
	Wind speed
	Wind direction

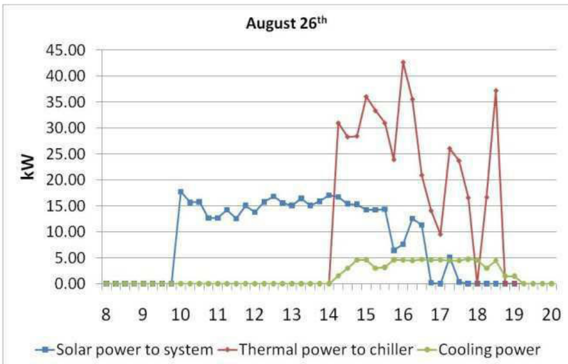

Fig. 3: August 26, measured thermal power

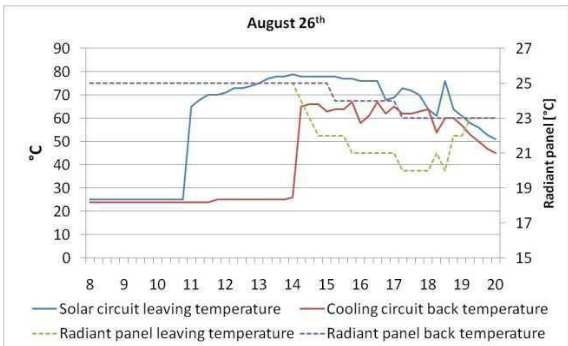

Fig. 4: August 26, measured temperatures for solar loop circuit and radiant panel cooling circuit (both constant flow rate)

Solar energy collected	Energy used by the chiller	Cooling energy	Heat rejected	Average COP chiller
kWh	*kWh*	*kWh (-)*	*kWh*	
6107	3891	1468	5215	0.38

Table III. – Energy balance and average COP for the period August 22 - September 11, 2011

Chiller average COP in terms of energy, power and temperatures hourly profiles for typical days, and global COP and Solar Fraction will be reported in the full paper.

3. Validation of the numerical model

Polysun software has been used to simulate the hourly performance of the system.

Since building demand dynamics is not modelled accurately in Polysun, an auxiliary model of the building has been realized and run in Energy+. Data from this simulation have been used to set the Polysun simplified building model, in order to obtain the best fit with simulation.

Measured weather data have been used as input, and the results of simulations have been compared with measured data. Some parameters of the simulated control had been changed, in order to better cope with actual data. A good agreement has been eventually obtained.

4. Results of parametric analysis

A parametric analysis has been performed using the validated model.

Main task of this work was to verify the effect of the application of different types of solar collectors, different control setpoints (example in Fig. 5) and different heat rejection sinks.

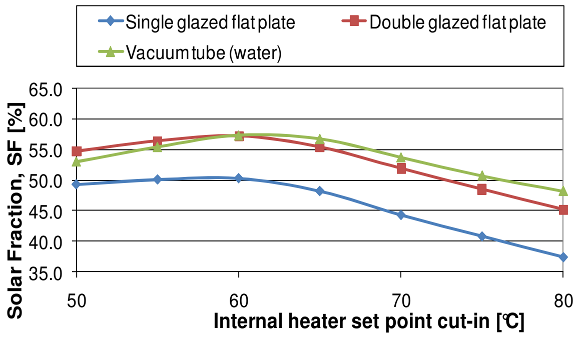

Fig. 5: Solar fraction as a function of the boiler supply heating setpoint for 3 types of solar collector

As an example, the application of double glazed collector instead of the single glazed one is presented hereby. Considering the same heat rejection system (dry cooling) and same tank temperature setpoint, it would have increased the solar fraction performance by almost 20%.

5. Conclusion

Solar cooling using sorption chiller may not be a new technique, but it's still in its young age. In this work a recent installation in Northern Italy has been monitored for three weeks. A rather satisfactory performance has been measured, though some problems arises in the management of the system during the observed period.

A multiple parametric simulation of the system, based on a numerical model validated with the actual configuration and meteo data, has been carried on. Output revealed some concrete possibilities of enhancing the performance of the system, with almost the same initial cost, that should had been considered during design and installation stages.

The analysis has underlined the strong importance of a well balanced design, that should cover in depth the non-converging scopes of improving solar system efficiency, reducing tank volume, simplifying heat rejection circuit and improving chiller performance. This theme will be extensively addressed in the final paper.

Acknowledgement

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References

[1] H-M. Henning "Solar assisted air conditioning of buildings – an overview", Applied Thermal Engineering, Vol.27 (2007) pp.1734–1749

[2] J.A.Duffie, W.A.Beckman, Solar engineering of thermal process, Wiley, New york 3rd ed. (2005), pp. 588-617

[3] F.Agyenim, I.Knight, M.Rhodes "Design and experimental testing of the performance of an outdoor LiBr/H2O solar thermal absorption cooling system with a cold store", Solar Energy, Vol. 84 (2010) pp.735–744

[4] L. Schnabel, M. Tatlier, F. Schmidt, A. E. Senatalar "Adsorption kinetics of zeolite coatings directly crystallized on metal supports for heat pump applications (adsorption kinetics of zeolite coatings)", Applied Thermal Engineering Vol. 30 (2010) pp.1409-1416