Small Capacity Solar Cooling: Two Systems Installed in the Frame of the Project "SOLERA"

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Abstract

Two solar cooling systems were installed recently in the frame of the EC co-funded project "SOLERA" [1]. A 4.5 kW absorption chiller from the Spanish company Rotartica was installed at the premises of the Institut National de l'Energie Solaire (INES) in Chambery, France. A solar system of the French company Clipsol provides the driving heat and a horizontal ground heat exchanger is used as a heat rejection unit. The system is in operation since summer 2008 and is used for heating and cooling.

A second system with 17.6kW cooling power (Yazaki WFC-SC5), 61.6m² of flat plate collectors (Riello, Italy) and a 5m³ buffer storage was installed at the premises of the company Riello close to Venice in Italy. The system provides cooling for an office building of the partner Riello. A particular feature of this system is the use of an electric driven reversible heat pump as back-up system both heating and cooling. This system is in operation since December 2009.

The first operation results of the first system are presented in this paper. We give special attention to the solar contributions for heating and cooling as well as the electricity consumption of different elements and the whole system.

1. Introduction

The goal of the project SOLERA is to install, operate and evaluate three different solar cooling systems of different sizes. Two of the systems have been installed and are in operation. The third system, where the use of a Fresnel linear concentrating collector is planned, has not been installed yet. An extended monitoring period to improve the operation and optimize the performance is a key element of the project. We put special dedication into the evaluation of the electricity consumption of the components and the whole systems in order to identify improvement potential. Further, the primary energy ratio as defined in the IEA-SHC Task 38 [2] is evaluated.

2. Demonstration systems

Two out of three demonstration systems planed in the project have been installed. In one case a compact system with a cooling power of 4.5 kW was installed in France, the second system is a 17.6kW cooling power system installed in Italy. While the system in France has been installed at the end of 2008, the system in Italy has been finished in December 2009. Several technical problems during the installation and commissioning of the Italian system resulted in little monitoring data. Thus in this paper we will discuss only the results of the French system.

3. Demonstration system in Chambery / France

3.1. System description

The demonstration system in France is installed at the 'Institut National de l'Energie Solaire' (INES) close to Chambery. The system was planed and set-up by the company TECSOL, a partner in the project, in collaboration with INES. It is used to cool three offices of INES. Fig 1 shows a scheme of the system.

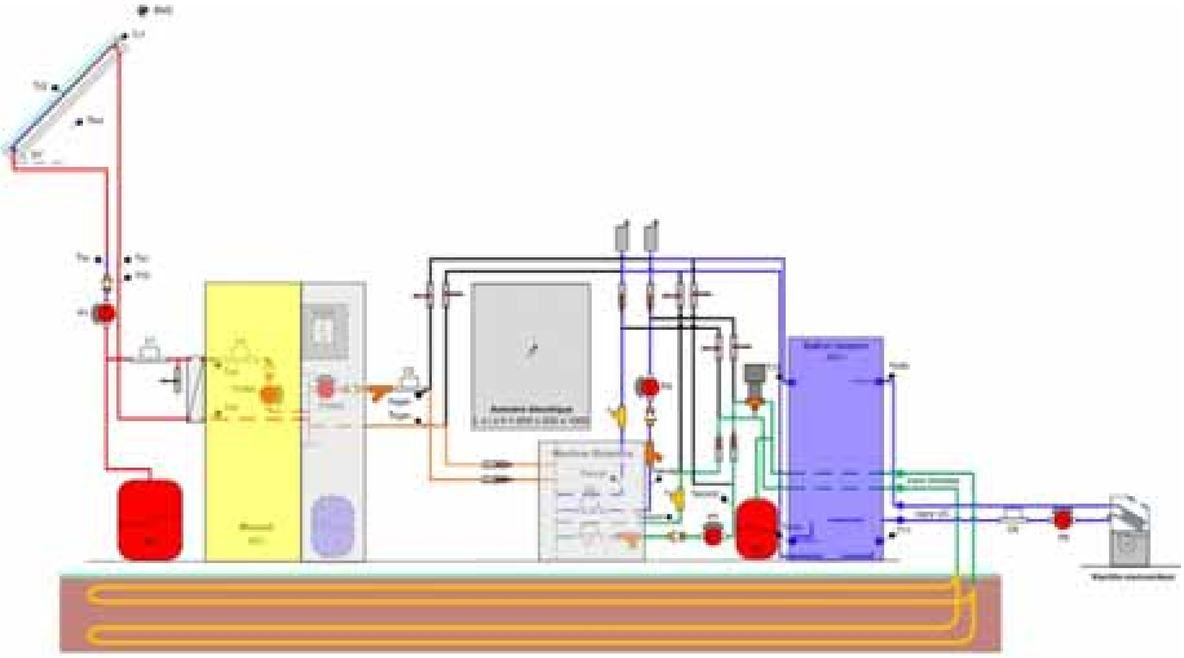

Fig. 1. Scheme of the solar cooling system installed at INES / France.

The following components are installed:

- A solar system with 30m² of flat plate collectors and a 400l hot water buffer storage. A 12kW electric back-up booster is installed in the hot water storage tank to guarantee domestic hot water in the hot water station in case it is needed. Collector and hot water storage are separated by a plate heat exchanger provided by CIAT. The electric booster is disabled in summertime in order to avoid the use of electricity for cooling. The solar system has been provided by the company CLIPSOL which is also a partner in the project.

- An absorption chiller from the Spanish company ROTARTICA. The nominal cooling power of the chiller is given at 4.5kW with a thermal COP of 0.62 at driving temperatures of 90°C, heat rejection temperatures of 40°C and chilled water temperatures of 16°C. In this project the model without the integrated cooler was selected as the heat rejection is assured through a field of ground heat exchangers. Unfortunately since the end of 2008 this chiller is not offered on the market any more. The company Fagor Electrodomésticos, owner of Rotartica, took over the follow-up and maintenance of the installed machine.
- Heat rejection: a large horizontal ground coupled heat exchanger was installed for this purpose. The field consists of two networks, one at a depth of 0.75m, a second at 1.1m. The total area of the heat exchanger is around 138m². The complete field is divided into 22 independent sections. This allows the test of several different configurations and sizes during the monitoring phase.
- Heat and cold distribution is carried out by roof mounted fan-coils provided by the company CIAT. They have been designed for a chilled water operation temperature of 13/18°C in the cooling mode and heating water temperatures of 38/35°C in the heating mode. A 300l chilled water storage was installed for hydraulic reasons between the chiller and the distribution network.
- Load: The load of the three offices, with an approximated area of 21m² each was estimated at about 1.5kW for cooling and 3kW for heating for each office.

3.2. Operation results

The system was installed at the end of 2007 and is in operation since February 2008. Although already in operation in the summer 2008, this period was characterized by constant changes and modifications in the system adapting operation and control procedures. Further, the offices were only used since the year 2009. Thus regular operation and monitoring data suitable for evaluation is available for the summer period of 2009. In Fig. 2 the overall results for this period (May to September) is shown.

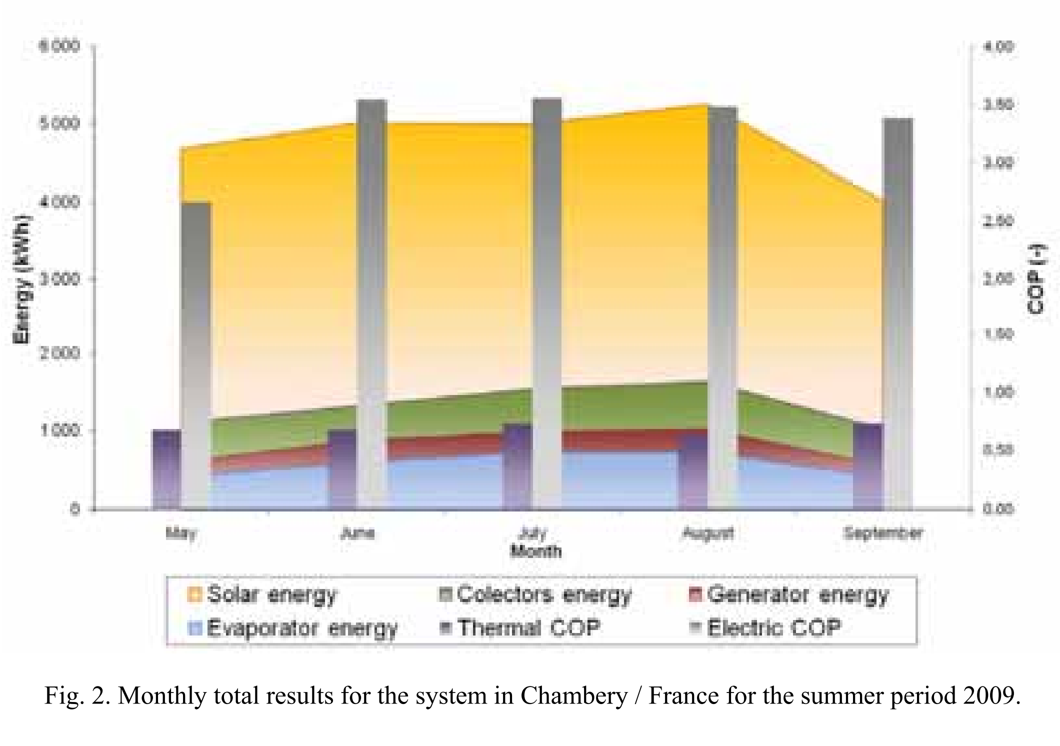

Fig. 2. Monthly total results for the system in Chambery / France for the summer period 2009.

The cooling was operated purely solar driven. This means, that cooling was only provided if the buffer storage was heated up sufficiently by the solar collectors in order to provide the driving heat for the chiller. For this particular chiller this meant that the storage should have reached a temperature of at least 80°C. For the complete 2009 summer period, the following results were achieved:

- The overall solar system efficiency, defined as the ration between the used heat from the system and the incidence radiation, was 27%
- A total amount of 2840kWh of cold was provided to the load
- The thermal COP of the chiller over the whole period was 0.7
- The electric COP of the system was 3.34.

Fig. 3 shows a temperature curve for a typical sunny summer day (September 10th, 2009). It can be seen, that the operation of the chiller starts late in the morning (at about 11:45) and ends early in the afternoon (at about 16:45). During this period sufficiently high temperatures to drive the absorption chiller are measured in the hot water storage. The heat rejection temperatures, which are provided by the ground coupled heat exchanger are favourable and reach a maximum of 32°C.

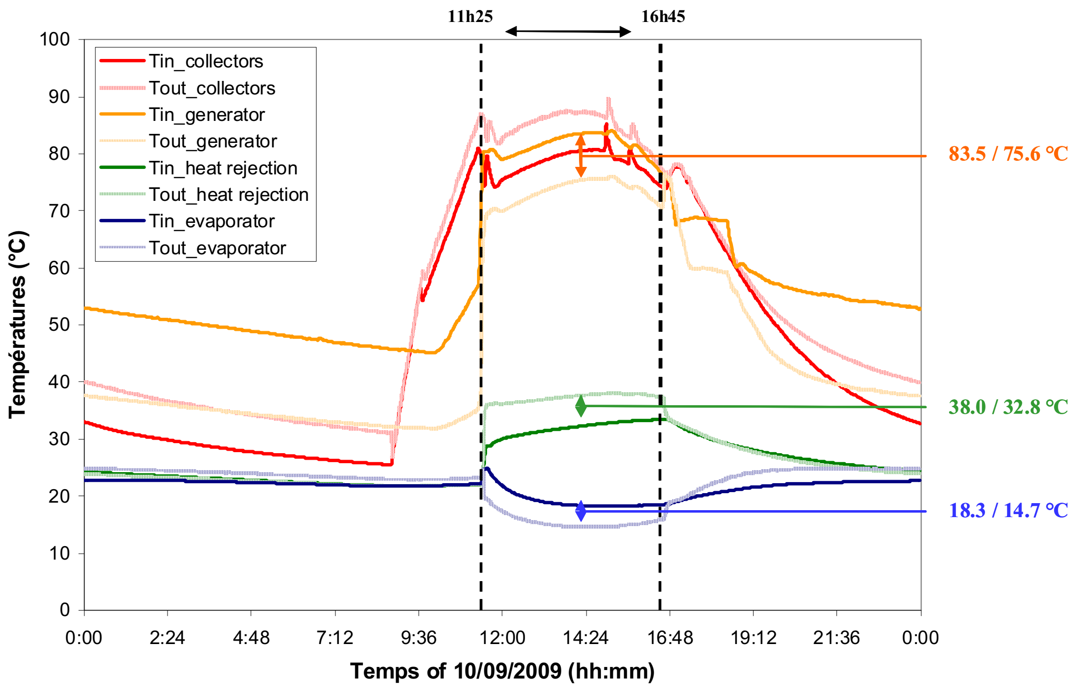

Fig. 3. Temperatures in the collector loop, the generator loop of the chiller, the heat rejection loop and the chilled water circuit on September 10th, 2009.

Fig. 4 shows the powers for the same day and in Table 1 the numeric results for the thermal and electric energy are summarized. From the energy balance it can be deduced, that the thermal performance of the system is very good, reaching a total thermal COP of 0.75 for the whole day and the mean chilling power was 5.4kW. On the other hand, the electric COP of the system is not very good: in spite of the high thermal power and the continuous operation over 5 hours and 20 minutes (11:25 to 16:45) the electric COP reaches only a value of 4.84. Analysing the electricity consumption of specific components it turns out, that the chiller itself is a large consumer of electricity: its share is more than 25% of the electricity consumed by the whole system. This gives a mean electricity power requirement of 420W for the chiller. The main consumer is the electric motor for the rotating thermal unit, which is a specific characteristic of this machine.

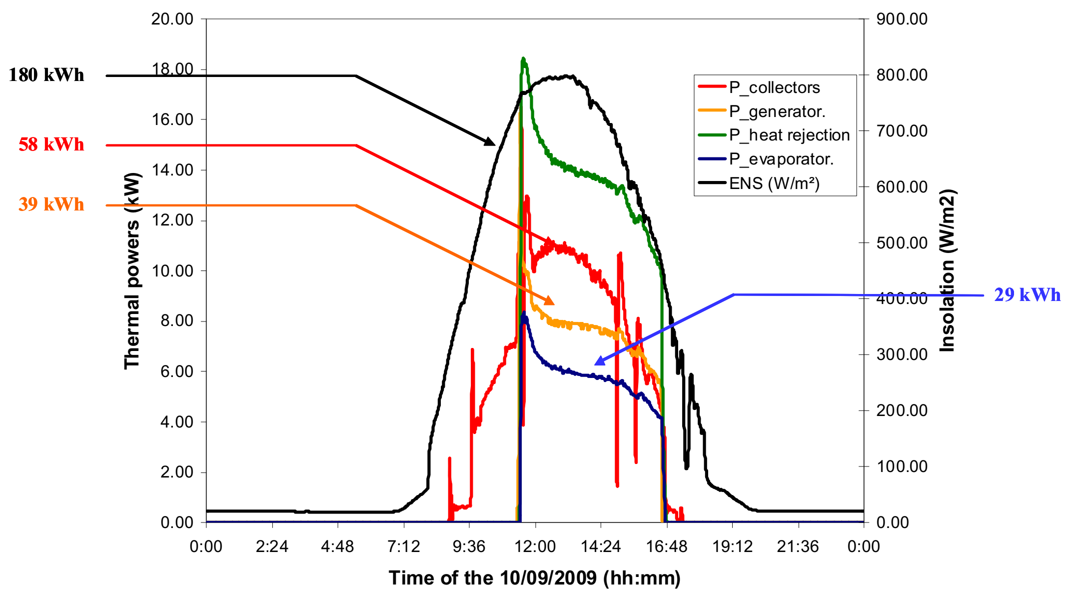

Fig. 4. Powers measured for the system on September 10th, 2009. The radiation curve shows that it was a sunny day with a maximum total irradiation power of about 800W/m².

Table 1. Thermal (left) and electric (right) energy balance of the system for September 10th, 2009.

Parameter	**Unit**	**Value**
Radiation	kWh	180.86
Solar System	kWh	57.64
Generator	kWh	38.82
Evaporator	kWh	29.02
Distribution	kWh	31.54
System efficiency	-	0.32
Thermal COP	**-**	**0.75**

Parameter	**Unit**	**Value**
Electric consumption (total)	kWh	8.61
of which:		
Solar system (without distr.)	kWh	5.99
Chiller	kWh	2.26
Distribution	kWh	0.36
Electric COP	**-**	**4.84**

In order to evaluate the suitable size of the ground heat exchanger for this system and chiller several experiments with a partially disconnected field were carried out. The large thermal inertia and the slowly heating up of the affected ground area (a mean temperature increase of the about 5K in the affected area was measured) makes it impossible to give a definitive answer to this question. Nevertheless, the experiments indicate that the ground heat exchanger could be about 20% smaller without significant effect on the chiller performance.

4. Demonstration system in Piombino Dese / Italy

4.1. System description

The second system was installed in Piombino Dese, close to Venice. The system is installed at the premises of the company Riello S.p.A. providing air-conditioning for an office building of the company. Riello also provided the flat plate collectors from their own production. The system was planned and installed by the Politecnico di Milano and the Riello company. Fig. 5 shows a scheme of the system.

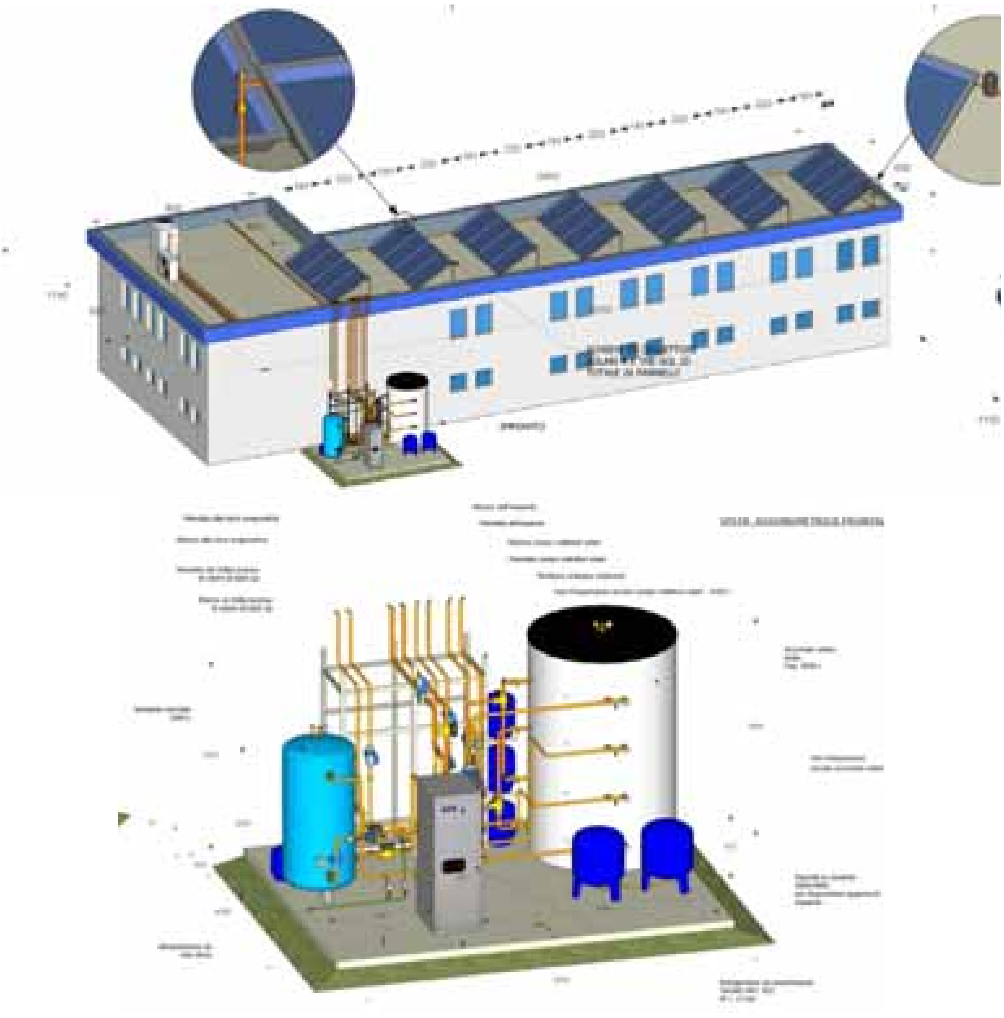

Fig. 5. 2 Schematic of the installation in Italy: the solar collector field (top) and the configuration of the cooling system including chiller, hot and chilled water storage (bottom).

The installed components are:

- A flat plate collector field of 61.6m² absorber surface (28 collectors of the company Riello, THE/SOL 25)

- A Yazaki WFC-SC5 Lithium-bromide absorption chiller with 17.6 KW cooling power at the operation temperatures of 88°C/83°C in the generator, 31°C/35°C in the heat rejection circuit and 7°C/12°C in the chilled water loop. The nominal COP is rated at 0.70.
- A wet cooling tower of the company Evapco (ICT 3-63) with 42.7KW nominal power
- A 5000l hot water buffer storage
- A 1000l cold water storage
- A reversible electrically driven air-to-water heat pump Sintesy 046HP of the company Riello as back-up for heating and cooling. The nominal power is 14KW both for heating and cooling. The heating-COP with hot water temperatures of 45°C and ambient temperatures of 0°C is rated at 2.74. With ambient temperatures of 7°C it increases to a nominal value of 3.21. For cooling applications the values are: 3.59 for chilled water temperatures of 7°C and ambient temperatures of 30°C. This value is reduced to 2.8 of the ambient temperature increases to 35°C.

The components were dimensioned on the basis of system simulations carried out with the TRNSYS software package. Several parameter variations were carried out in order to find the optimal size of the components according to the expected load. The system is installed, has been commissioned and monitoring data is currently being collected.

5. Conclusions

The results of the system in France show, that the expected thermal performance can be easily reached with a good design of the system. The ground heat exchanger also proved to be a suitable and reliable heat rejection system for thermally driven chillers. Nevertheless, the electric COP of the system is still its biggest problem. In this case, the electricity consumed by the chiller itself, due to its particular construction, is a mayor portion (more than 25%) of the overall electricity demand. Thus the overall electric COP for the summer period 2009 reached a value of only 3.7. A value of 4.8 can be reached on a sunny summer day.

Further, the installation and commissioning process shows, that a considerable time is necessary to set-up the system, achieve a regular and optimized operation. Up to 6 months can be necessary in order to get the systems running as expected. This experience shows the importance of longer monitoring periods for demonstration systems and the requirement of a certain amount of sensors to check and evaluate the functionality of all components also in future series product. In general, at least two summer periods are necessary to obtain reliable monitoring data of regular operation from demonstration systems.

References

[1] www.solera-project.eu

[2] W. Sparber et al., 2008. "Unified Monitoring Procedure and Performance Assessment for Solar Assisted Heating and Cooling Systems". 1st International Conference on Solar Heating, Cooling and Buildings. EUROSUN2008, Lisbon, 2008.

Acknowledgement

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