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DHW/Cooling Hybrid Strategy for Solar Cooling: One Successful Year Monitoring Results

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Abstract

Within the framework of the French program called Emergence aimed at financing high quality solar heating and cooling demonstration projects, a first solar cooling installation was designed in 2011, then installed and monitored since the beginning of 2013. This installation is based on an innovative and energy efficient concept to optimize solar energy valorization all year long: hybrid solar Domestic Hot Water and cooling strategy. This installation has been fully monitored from spring 2013 until spring 2014 with cooling / DHW production and permits to show the high interest of such strategy to combine long term quality, simplicity of use and economical efficiency. In summer 2013, the hybrid strategy led to a very promising electrical efficiency (or Electrical COP) of more than 12 (ratio between useful solar energy (cooling and DHW) and electrical parasitic consumption).

1. Context

Solar thermal heating and cooling systems are usually used in tertiary buildings. For such buildings located in Southern part of Europe where solar resource is very important in summer as well as cooling load, the valorization of solar energy in winter and inter-seasonal periods can be an issue, especially in modern and energy efficient buildings (Henning, 2004). In these cases, the use of solar energy through heating systems is weak in winter and inadequate during inter-seasonal periods. Besides, domestic hot water (DHW) needs of tertiary buildings are quite small, finally leading to a poor annual solar yield and overall electric efficiency. In the case of the present project, a building mixing both tertiary offices and residential dwellings has been found and equipped of a solar thermal system, allying both chilled water production in summer and Domestic Hot Water production all year long.

2. System presentation

Basically, most of large domestic hot water systems for dwellings in southern part of Europe are sized according to the maximum solar fraction occurring in summer time (generally 80 to 85%) leading to average solar fraction of 20 to 30% in winter time and then average overall annual value of 50%. As a consequence, if the solar collector field is oversized, there is a risk of overheating in summer. To tackle this overheating risk in summer dimensioning the potential collector area, a valorization of a part of this energy for cooling is particularly appropriate. This solution permits to increase the solar fraction and get an optimal solar yield. A technical solution has been found for an existing block of 2 buildings linked with a micro heating and cooling network (see Figure 1). One of the buildings is dedicated to tertiary activities while the other one is dedicated to dwellings and for a supermarket. In winter, solar energy is used for DHW production only. In summer, the installation will produce DHW and cool down the building simultaneously. The size of the thermally driven chiller has been selected with caution to both satisfy DHW and chiller generator loads.

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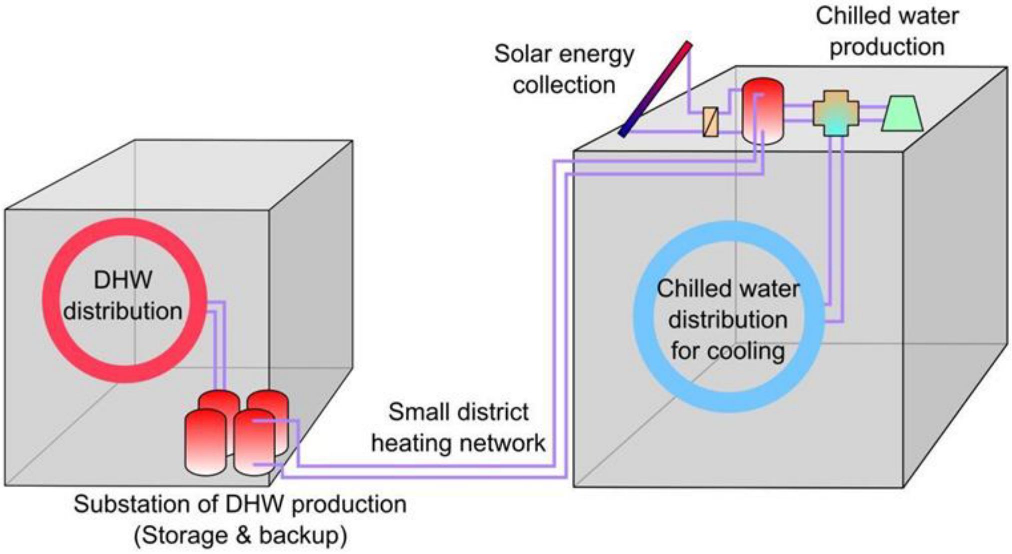

Figure 1. Hybrid DHW/cooling strategy concept with micro district heating network

The working principle of the system is actually very simple: During winter, only domestic hot water is produced with the energy of the sun. At this time of the year, the solar fraction will be higher than for usual solar domestic hot water (DHW) production system, because the collector field is a bit oversized in comparison to the DHW loads of the building.
During inter-seasonal periods, because of the relative over-sizing of the installation, the system will start to overheat if the installation keeps producing DHW only. So the mode is switched to a combined chilled water and DHW production at the same time, to supply the tertiary offices with chilled water for cooling, and the dwellings with DHW.
Between these two types of buildings needing two different types of distribution, there is a micro district heating network in order to link them.
The detailed scheme of the system is quite usual for an absorption solar cooling installation, and it is shown on Figure 2. However there is some specificity which will be explained here.

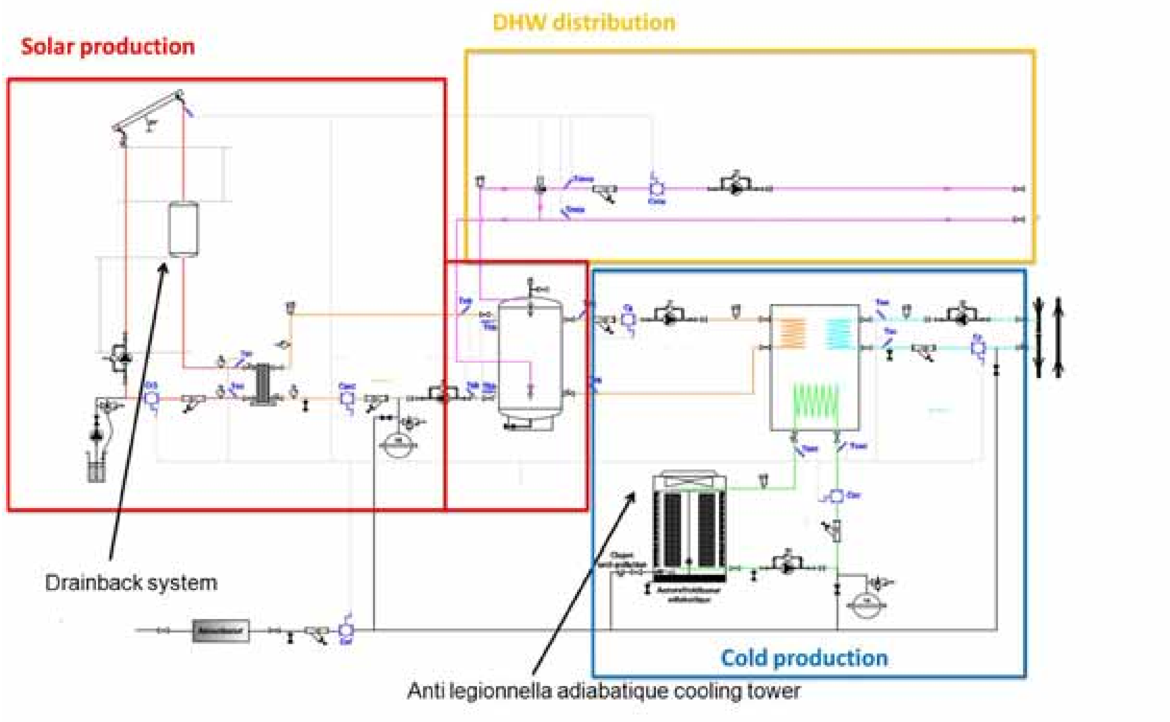

Figure 2. Detailed scheme of the system

Because of the large size of the collector field, it was chosen to secure the installation against overheating and freezing risks thanks to a drainback system (Mugnier et al. 2011) : in these conditions, the circuit is filled with fluid (glycol water) and air, in a closed loop. And the collectors are automatically drained as soon as the

solar primary pump is turned off. This technique offers a very efficient and very simple way to secure completely the collectors against overheating and freezing.
An important specificity of this system is the 3 way valve installed after the hot buffer storage. When the chilled water and DHW are produced simultaneously, a specific regulation of this 3 way valve permits to control how much energy is sent to the DHW substation and how much energy is kept in the buffer storage. So the temperature on top of the buffer storage is always close to the optimal working point of the absorption chiller.

Another noticeable specificity in this system is the rejection heat system. Indeed, in France, legislation against legionella is strict and leads to specific sanitary safety measures. As a consequence, when a cooling tower or even a hybrid drycooler are used, the French regulation impose the system owner to carry on very frequents and expensive water testing. Moreover, a simple drycooler wasn't an option because it's not possible to decrease cooling water at a temperature lower than the ambient one. And finally a geothermal field would have been very difficult to implement because the area is quite urbanized, and the chiller is installed on the 8th floor. As a consequence an adiabatic cooler was chosen. This type of coolers permits to cool down the cooling water below the air temperature, and doesn't require water testing.

Figure 3. Partial view of solar collector field (double glazed flat plate collectors)

The installation's main characteristics are listed below:
- Targeted building: group of 2 buildings with offices, and dwellings.
- Solar collectors: high efficiency drainable flat plate collectors, 240 m² (Fig. 3)
- Collector field secured against overheating and freezing with a drainback technology
- Chiller: simple effect Lithium Bromide absorption chiller, 35 kW nominal cooling capacity
- Heat rejection: adiabatic cooler, low electric & water consumption, no risks of Legionella
- Domestic Hot Water production: 10000 liters storage
- Backups: conventional compression chillers for cooling and gas heaters for DHW production

3. Monitoring results

The solar system, located in South of France in Montpellier, has been working continuously from May 2012 until end of July 2014 without critical technical issues even showing remarkable performances. The monitoring data of the system have been exploited from March 2013. This system has then acquired one full year monitoring data which will be presented in ht next paragraphs of this paper, especially the cooling season performances from July to August 2013.

From an energy balance approach, the monitored results on the period of these 2 months in summer 2013 show the data in Figure 4. It is giving the detail per day on the performance of the system, showing that the cooling system have worked nearly 90% of the time in these 2 months in South of France. This information is showing the system was very reliable during the cooling season:

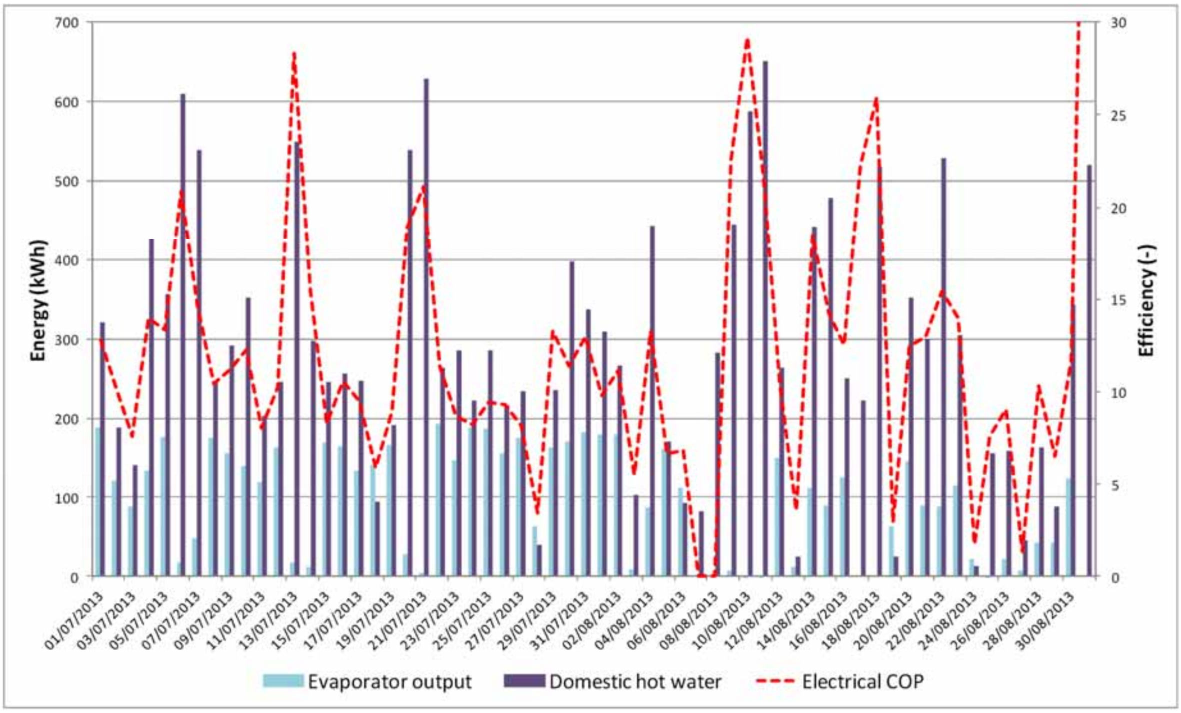

Figure 4. Energies and electrical COP for the cooling season in 2013 (July and August 2013)

It can be concluded that this solar cooling system has given very good performances on the domestic hot water preparation as well as for the cooling period, without any technical operation issues. According to the preliminary feasibility study (Siré et al., 2010) simulated results announced an average Electrical COP during July and August of 14.7 while the monitored results gave a real value of 12.2. It is to note that this value leads to a very slight discrepancy between measurements and simulation. Nevertheless, while the simulation planned a share of DHW among the total solar production in July/August of nearly 16%, the measurements gave a share of 75% of the total solar production. Simultaneous DHW and cooling loads permitted to the solar energy to be fully used even if the cooling load was smaller than expected.
In summer 2014 until end of July, the solar irradiation was sensibly less than in 2013 with nearly 15% less irradiation in Montpellier (on the average of the 2 months of June and July in 2013 and 2014). However, the results obtained in 2013 were confirmed (proportionally to the difference of irradiation).

	DHW Production (kWh)	Cooling Production (kWh)	Parasitic elec. Consumption (kWh)	Useful Solar Yield (kWh/m2)	Overal elec efficiency (-)
from 18/03/2013	4 654	0	110	19.4	42.3
april 2013	11 588	0	290	48.3	40.0
may 2013	16 478	0	380	68.7	43.4
june 2013	7 497	2 765	902	42.8	13.4
july 2013	9 482	3 983	1 190	56.1	13.5
august 2013	8 628	1 970	840	44.2	14.2
september 2013	9 316	676	554	41.6	18.9
october 2013	7 843	0	240	32.7	32.7
november 2013	4 789	0	220	20.0	21.8
december 2013	3 851	0	157	16.0	24.6
january 2014	3 734	0	190	15.6	19.7
february 2014	6 435	0	218	26.8	29.5
march 2014	12 860	0	348	53.6	30.9
april 2014	14 085	0	360	58.7	39.1
may 2014	12 633	281	326	54.0	40.2
june 2014	8 847	944	685	39.7	15.2
july 2014	5 586	2 959	851	26.8	12.4
TOTAL	148 308	13 578	7 861	**674.5**	**20.6**

** elec consumption linked to the solar useful production (pumps solar, DHW, generator, evaporator, condensor circuits) without measuring back up elec consumption.*

Figure 5. Energies and electrical COP for the 16 months monitoring (from March 2013 to July 2014)

According to Figure 5 showing the balance for the 16 monitored months, a very good value of 20.6 is obtained on the overall electrical efficiency of the solar system for DHW and cooling which means the system produced 20 times more thermal energy (cooling and heating than it used electricity to run). The solar collection was efficient thanks to the solar double glazed collectors as well as thanks to the efficient absorption chiller (average monthly value of 0.62 for the COP) reaching a value of 674.5 kWh/m² over the 16 months which means a value of nearly 500 kWh/m².year for the useful solar yield of the system.

4. Conclusions

Even if solar DHW/cooling system concept cannot be systematically replicated, the installation is an example of a very promising 'hybrid' solution permitting to mix performances, reliability and simplicity. Solar cooling technology strongly needs to be implemented in such cases where solar energy is highlighted with an optimum economical efficiency and a reduction of malfunctioning risks due to overheating. This system is giving a very interesting feedback on how to integrate solar cooling technology in an existing group of buildings showing the concept is promising but must face important integration issues.

5. References

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6. Acknowledgements

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