SolarCooling Monitor – Evaluation of energy efficiency and operation modes of solar cooling systems for air-conditioning in buildings in Austria

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Abstract

Between 2007 and 2009 sixteen new solar cooling plants for building air-conditioning were installed in Austria. The "SolarCooling Monitor" project aims as giving an overview of the current installation quality of solar cooling plants in Austria as well as the efficiency and operation performance. Therefore, ten of the newly installed solar cooling plants in Austria as well as one large-scale installation in Lisbon, which was realized by the Austrian plant engineering and Construction Company, were selected, in order to examine the performance by means of monitoring and simulation. The measurement procedure follows the framework of IEA SHC Task 38 level 3 [1] and the results will be presented at the next expert meeting.

Within this conference paper, the goals, methodology and first results of the project "SolarCooling Monitor", which was funded by the Austrian national funding programme "Haus der Zukunft Plus", are presented. These first results and experiences referring to summer 2009 comprise:

- strengths and weaknesses of the solar cooling plants concerning coefficient indicators and operation performance
- experiences from operation of selected solar cooling plants

Keywords: solar cooling, monitoring, evaluation

1. Introduction

The current situation concerning solar cooling plants in Austria can be summarized in two points:

- At present, there is still hardly any experience in the operation of solar cooling systems in Austria. Since experiences of plants in operation are missing, empirical values of a monitoring (if at all available) only give a partial explanation about the plant efficiency. In particular, this is also valid for the peripheral power consumers such as pumps, fans etc. A comparison of the continuous actual values according to monitoring with desired values from a dynamic simulation can make this possible.

- Plant owners who invest much money into the solar thermal cooling installation are often missing a professional evaluation of the functionality and optimization of the plants.

2. Project goals

The project aims are

- to provide an overview of the present quality of workmanship of solar cooling plants in Austria
- to increase the know-how about plant operation of solar cooling systems already in operation (plants in Austria and one large-scale installation in Lisbon)
- the alignment of simulation results of solar cooling with actually measured plant performance

3. Methodology

Ten of the newly installed solar cooling plants in Austria were selected, as well as one large-scale installation in Lisbon, which was realized by the Austrian plant engineering and Construction Company, in order to examine the performance by means of simulation and monitoring:

- Implementation of monitoring equipment to evaluate the main working conditions of the solar cooling plants
- Comparison of the actual values according to monitoring with desired values from a dynamic simulation
- Simulation of optimization scenarios; recommendations to plant owners for plant optimization
- Summary and dissemination of outcomes

		1	2	3	4	5	6	7	8	9	10	11
Location	Austria	x	x	x	x	x	x	x	x	x	x	
	South Europe											x
Status	Already built	x	x	x		x	x	x		x	x	x
	In planning/construction				x				x			
Cooling technology	Small scale absorption system (<20 kW)									x	x	
	Absorption system middle range			x	x		x	x	x			
	Large scale absorption system (>400 kW)											x
	Small scale adsorption system (<20 kW)		x			x						
	DEC-System	x						x				
	Compression system (monitored)			x								
Back-up	100% solar driven	x	x			x		x		x	x	
	Hot side Back-up						x		x			
	Cold side Back-up			x	x							x
Solar thermal collectors	Flat plate collectors	x	x	x	x	x	x			x	x	x
	High efficient flat plate collectors							x	x			
	Facade integration/roof integration	x			x	x				x		x
Heat rejection	Wet cooling tower			x	x		x	x	x			x
	Hybrid heat rejection		x			x				x	x	
	Earth				x							
Energy distribution	Central ventilation system	x		x	x			x				x
	Cooling ceiling							x	x	x		
	Concrete core activation/floor heating	x			x		x				x	
	Fan-Coils		x	x				x		x		x
	Blowing fan from ceiling					x						

Table 1: Classification of selected solar cooling plants (1 = ENERGYbase Vienna; 2 = MA34 Vienna; 3 = BH-Rohrbach; 4 = Fa. Sunmaster, Eberstalzell; 5 = Fa. Kreuzroither, Schörfling; 6 = Fa. Gasokol, Saxen; 7 = Town Hall Gleisdorf; 8 = Feistritzwerke, Gleisdorf; 9 = Fa. SOLID, Graz; 10 = Fa. Bachler, Gröbming; 11 = Caixa Geral de Depósitos - CGD, Lisbon)

Table 1 shows an overview of the used cooling technologies, back-up strategies, solar thermal collector technology, heat rejection technology and energy distribution in the selected solar cooling plants.

4. First Results

4.1 Status of operation

- Solar cooling systems in operation in summer 2009: ENERGYbase , MA34 , BH-Rohrbach, Sunmaster, Gasokol, Town Hall Gleisdorf, Solid, Bachler , CGD-Lisbon
- Planned for summer 2010: Kreuzroither, Feistritzwerke Gleisdorf
- Monitoring results available from summer 2009:
- Whole summer: MA34, BH-Rohrbach, Town Hall Gleisdorf
- Partly recorded data: ENERGYbase , Solid, Bachler
- No monitoring data: Fa. Gasokol, Fa. Sunmaster, CGD-Lisbon

4.2 Evaluation of strengths and weaknesses of solar cooling systems concerning operation modes and system performances

The following strengths and weaknesses occurred in the up to now analysed solar cooling plants:

Strengths:

- One competent contact person
- Thermal COP
- Electrical COP
- Volume flow regulation
- Understanding of operation of analysed solar cooling system

Weaknesses:

- Many contact persons
- Thermal COP
- Electrical COP
- Storage management summer/winter
- Small temperature differences between supply cooled water and return cooled water
- High electricity demand for heat rejection
- High back-up heating demand
- Bad part load system performance
- Unnecessary follow-up times
- Permanently running components: controller, regeneration only on/off + humidifier, safety relief valve
- Crystallisation in absorption chillers
- Component in solar thermal system destroyed by overheating: return valve in primary loop

- Complete or partly malfunction caused by insufficient commissioning or control
- Bad correlation between control cooling (chillers, air-handling unit) and control remaining system
- Traceability of control

4.3 Experiences from operation of selected plants

Town Hall Gleisdorf

The „Solar City Gleisdorf" decided to realize an innovative energy concept when renovating the old town hall and building a new Service Centre (see Figure 1) which was finally constructed in 2008. In the newly built Service Centre the technical room is situated to supply both buildings with domestic hot water, space heating energy and cold water for cooling. Cold water is produced by an absorption chiller which is powered by a solar thermal collector and a natural gas boiler. Additionally, the newly built Service Centre is equipped with a "Desiccant Evaporative Cooling" (DEC) system in combination with the air ventilation system. The main key figures of the solar heating and cooling system are:

Collector area:	304 m² (newly developed high temperature collectors)
Heat store:	4.600 litres
Absorption chiller:	35 kW
DEC - Air flow rate:	6250 m³/h; ca. 35 kW nominal cooling power

Figure 1: Photo of the old renovated Town Hall and the newly built Service Centre (source: AEE INTEC)

Selected monitoring results

- **Solar thermal system**

In Figure 2 an operating point on June 19th, 2009 at 13:00 (maximum irradiation) is evaluated. Solar irradiation was 950 W/m^2, ambient temperature was 32 °C, average collector temperature was 80 °C (15 K temperature difference between flow (T_Solar_primär_VL) and return (T_Solar_primär_RL) flow) and the measured power was 72 kW (at secondary side in the water circuit). This results in an efficiency of about 59 % of the complete solar thermal primary loop including all pipe losses and heat exchanger losses. According to the data sheet, the collector efficiency itself at this operating point is 65 %.

For the electrical SPF_{el} (seasonal performance factor) of the solar circuit including the two pumps from October 2008 to September 2009 monthly values of 56, 36, 25, 29, 52, 62, 63, 71, 74, 82, 76 and 74 kWh_{th}/kWh_{el} and for the full year 67 were measured. The efficiency of the heat store within the same period was calculated based on the energy balance and resulted in monthly values between 75 and 96 %, in average 91 % for the full 12-month period.

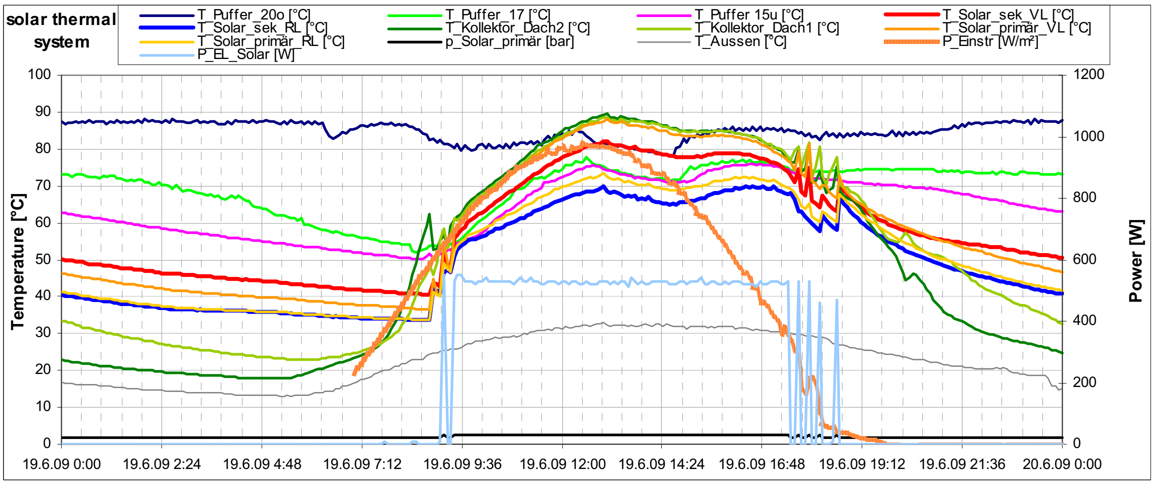

Figure 2: Temperature and solar irradiation (P_Einstr) of the solar thermal system on June 19th, 2009

- **Absorption chiller**

Most of the time the chiller is operating in a quite unstable "stop and go" mode (see Figure 3). The reason for that is, that if the minimum cold water temperature of 6.5 °C is reached, the chiller itself is internally switching off for a while, in order to avoid freezing of the water.

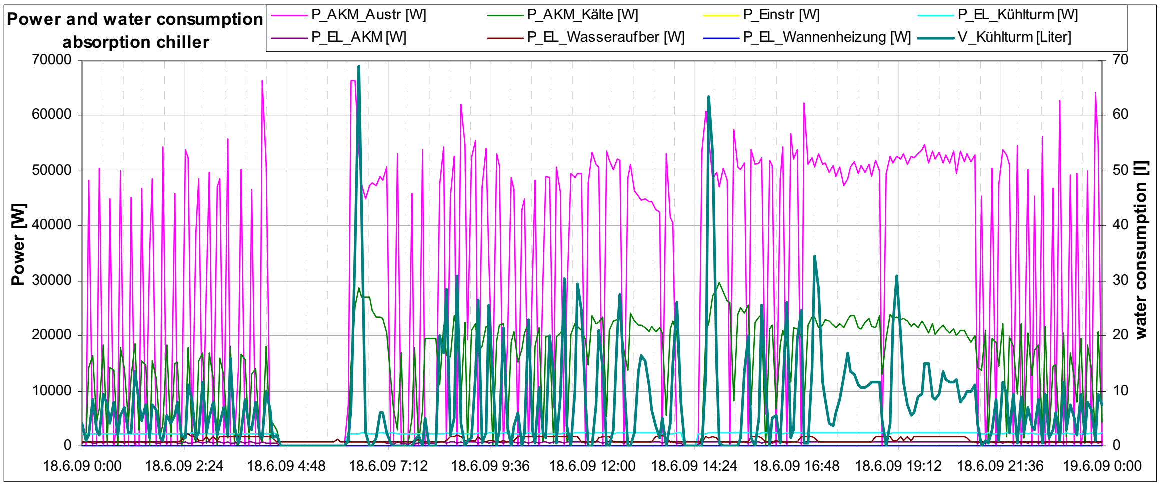

Figure 3: Heat capacity and electrical consumption around the absorption chiller on June 18th, 2009

After increasing of cold water temperature to more than 11 °C, the chiller starts cooling again. At about 14:00 the chiller is switching off, because the minimum generator temperature of 79 °C is not available any more. After about 30 minutes, the available temperature increased and the chiller started again. Nevertheless monthly electrical COP's of around 5 for cold water production could be achieved. More detailed evaluation and description of optimization steps of this solar heating and cooling plant is presented in [2].

ENERGYbase

The ENERGYbase building with 7.500 m² useful area is located in the 21st district of Vienna and was finished in July 2008 (see Figure 4). It is mainly used as an office building, but it also contains two universities of applied science and laboratory areas. The building was designed according to the "Passivhaus" standard, using renewable technologies to cover the heating and cooling demand. ENERGYbase is equipped with two identical air handling units "Desiccant Evaporative Cooling" (DEC) system with following key figures for the heating and cooling systems:

Collector area:	285 m² flat plate collectors
Heat store:	15.000 litres
DEC – Air flow rate:	2x 8.240 m³/h; ca. 78 kW nominal cooling power

Figure 4: Photo of newly built ENERGYbase building (source: Wiener Wirtschaftsförderungsfond)

Selected monitoring results

- **DEC-System**

Since the monitoring recording contained many gaps in July and August 2009, the data of the 22nd and 23rd of September 2009 were selected for the evaluations represented here. During these two days the DEC system operated with the use of solar energy in order to regenerate the sorption wheel (DEC mode) for around 8 hours each day. A first comparison of measured temperature values of two different position indicate a substantial difference (up to 5 K) between the temperature sensors of the weather station (WS-10) at the ENERGYbase and of the inlet position of the fresh air stream into the two DEC systems (see Figure 5).

A comparison of the meteorological data of UBIMET [3] with the measured data at the ENERGYbase (Figure 5) shows, that the measurements of the weather station corresponded to those of UBIMET. Consequently this fact indicates an air interchange between the fresh air and the exhaust air stream. Since the exhaust air temperature was very high on these two days in the DEC mode (up to 51°C), it affected on a higher fresh air temperature up to 5 K.

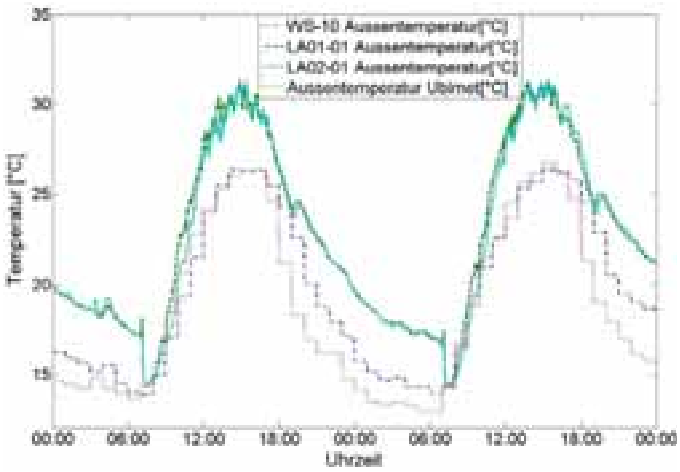

Figure 5: Comparison of measured outside air temperatures at ENERGYbase with UBIMET data; 22nd and 23rd of September 2009

In Figure 6 it can be recognized that after an initial overshooting of the regeneration air temperature the set value of 70°C (Klingenburg SECO 1770 sorption wheel) could be kept constant during the regeneration mode even in September.

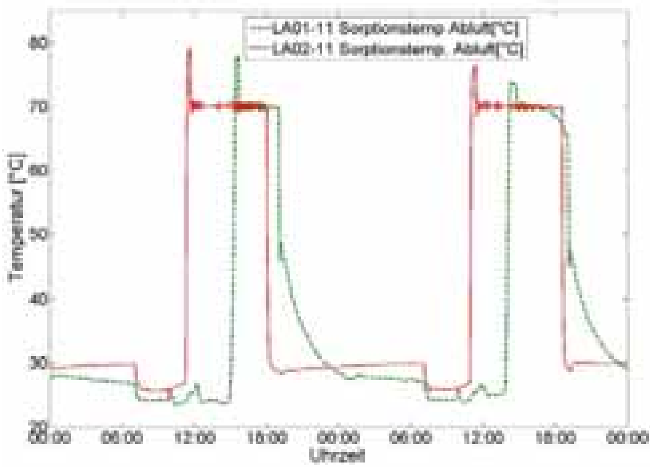

Figure 6: Exhaust air temperature after regeneration heating coil for both air handling units; 22nd and 23rd of September 2009

5. Conclusions

First conclusions concerning all analysed solar cooling systems:

- The continuous recording of monitoring data is a crucial point, which did not happen as expected in all solar cooling plants in the first year of evaluation. Therefore, all project partners were asked to improve the recording system (if necessary) until summer 2010.

- The list of strengths and weaknesses (see chapter 4.2) showed, that some solar cooling plants already achieve good energy performances (thermal COP, electrical COP), but there are also still some solar cooling plants which have to be improved. The list also shows, that according to the first impression of the project partners, there are many different problems to overcome in the different solar cooling plants.

Town Hall Gleisdorf

The first year of monitoring showed good results of the solar system with an electrical SPF_{el} (seasonal performance factor) of up to 82 kWh_{therm}/kWh_{el},, heat losses of the heat store between 4 and 25% and acceptable results of the single components like the absorption chiller and the DEC system during steady state conditions. Potential improvements for a better energy system performance are an optimized overall control strategy of the building in cooperation with the heat/cold delivery system and a reduction of parasitic electricity consumption, specially for water treatment.

ENERGYbase

For the positioning of the fresh air stream and the exhaust air stream of DEC systems, special care is required. In case of unfavorable positioning of these openings, an admixture from exhaust air to fresh air can take place. This causes a significant heating up of the fresh air, particularly in the DEC systems with high exhaust air temperatures. Concerning the solar thermal part of the system it could be shown, that the desired regeneration temperature can be achieved over the whole day even in September. For the evaluation of the overall system performance of the solar-assisted DEC system, continuously recorded monitoring data of July and August 2010 are crucial.

References

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