Development and Field Test of Complete Solar Cooling Kits: The Project "SolCoolSys"

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Abstract

Solar cooling with solar collectors and a thermally driven chiller is a well demonstrated technology for the air-conditioning of buildings. In a joint research project of the partners Fraunhofer ISE, SorTech AG and Solvis GmbH & Co KG a new integrated solar cooling kit is being developed and will be field tested. It is planned to install 10 systems in the power range of 8-30kW at the premises of interested customers in Germany and abroad. The systems will be equipped with a detailed monitoring system.

The goal of this field test is to gain operation experience and collect monitoring data under real conditions. This data will be used to evaluate the performance of the complete package, improve and optimize the design and operation of the whole system. The expected application is not fixed yet and will comprise residential as well as small commercial applications.

In this paper we present the system concept and hydraulic design as well as the monitoring and evaluation concept. As the sites for the installation are not chosen yet, the presentation also gives the opportunity to interested customers to participate in the project.

1. Introduction

Solar cooling systems are being installed since many years. Nevertheless, most systems today are non-standardised, custom design installations which are individually dimensioned and set together from market available components. Thus costs for planning and installation are high. While this might be acceptable for large systems where the investments costs are considerable, it s not viable for small systems as the relative share for the planning and installation rises into unacceptable and not competitive amounts. For small and medium system it is thus important to develop standardised packages which include pre-fabricated sets of components that can be assembled with a minimum of additional planning effort. Solar thermal systems, both for domestic hot water as well as for heating purposes are successful in the market only since complete 'plug-and-play' packages which included the hydraulic solar station, energy manager and an optimized control were available. These packages are optimized products which only need little adaptations in each case and can be installed easily by any local installer with little risk of mistakes and failure. Only pre-fabrication and assembly of components reduces the risk of installation mistakes which is essential for the reputation of any new technology. For solar cooling this step has not been done yet.

The goal of the project "SolCoolSys" is thus to develop complete solar cooling packages including the solar system, the chiller and heat rejection unit as well as the complete hydraulic connections including pumps, valves and control. The development is carried out around the adsorption chillers of 8 and 15kW chilling power provided by the company SorTech AG and a solar system of the company Solvis GmbH & Co KG. The package should be ready to be installed by experienced installers not requiring any additional dimensioning and design from their side. Thus the system will consist of pre-fabricated and factory pre-assembled components ready to be put together. This will reduce the risk of wrong design and dimensioning of the integrating components like pumps and valves and assure a reliable and coherent control of the whole system. Although a complete package is planed, we want to be flexible in the possible power range designing similar systems for one or several of the adsorption chillers. The sections below give a short insight of the project and system concept.

2. Project goals and structure

The central goals of the project are:

- Development of a complete solar cooling package based on solar systems of the company Solvis GmbH & Co KG and adsorption chillers of the company SorTech AG.
- Integration of the components developing pre-dimensioned, pre-fabricated and pre-assembled hydraulic units
- Adaptation of the standard components of the solar system (mainly the heat storage, considered as an energy manager) to the requirements for cooling
- Optimisation of the heat rejection unit and development of alternative concepts as this circuit consumes most of the auxiliary energy of the whole system
- Installation of 10 field test systems in real applications in Germany and abroad
- Monitoring of the field test systems by Fraunhofer ISE in order to evaluate the performance and optimise the operation. Some selected systems in Germany will be monitored in more detail by the University of Applied Science Offenburg.

The goals of the accompanying monitoring work are two:

- Supervision of the system in order to obtain operation data under real operation conditions. These results will be used to make an energetic evaluation of the whole systems.
- Optimisation and operation control: In addition, the monitoring is used to optimise the operation and control procedures based on the obtained results. This step will also contribute to the development of a system control which will include the essential sensors for the operation, supervision and fault detection of the future solar cooling system package.

2. System concept and hydraulics

The system will consist of a standard solar combi-system adapted to the heat requirement for the heating and cooling demand. An optional connection to the domestic hot water preparation as well as the provision of heat to the heating circuit is included. A stratifying buffer storage works as an energy manager providing heat to the different consumers: domestic hot water, heating and driving heat for the cooling. The cooling package consists of the adsorption chiller and the heat rejection unit. As a standard case a dry cooling tower with a water spray function to increase the heat rejection capacity under extreme conditions is used. But also boreholes or other heat rejection systems (pool, horizontal ground heat exchangers, wet cooling towers) can be considered. Fig. 1 below shows a schematic of the system.

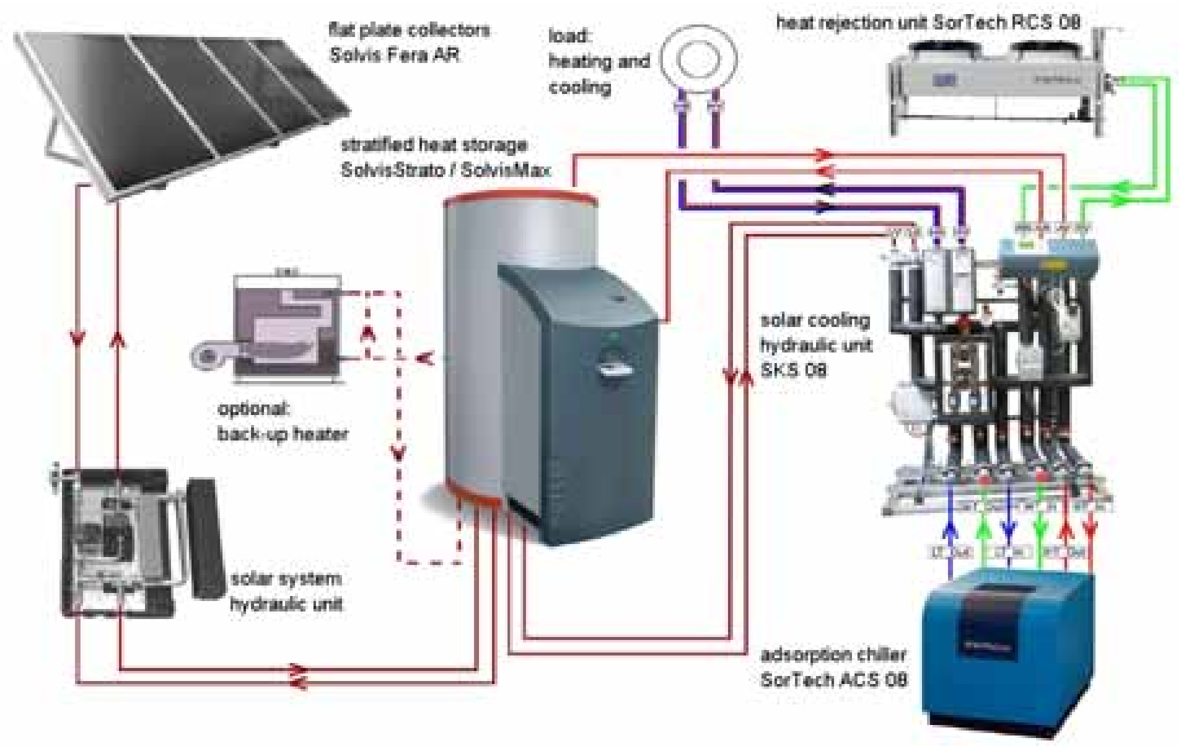

Fig. 1. System schematic: the stratifying buffer storage acts as an energy manager. A pre fabricated hydraulic switching unit distributes hot, cold and chillers fluids to the different components

A key component of the development is the pre fabricated hydraulic switching unit which will connect the three main components (solar system, chiller and heat rejection unit) in order to distribute and provide hot, cooling and chilled water to the different components and loads.

Several additional functions for the hydraulic switching unit will be analyzed:

- Use the heat rejection unit for free cooling when outdoor conditions are favourable
- Use the adsorption chiller as a heat driven heat pump. In this case, hot water provided by the back-up boiler is used to drive the adsorption machine, which pumps low temperature heat from the collector to the heating circuit.

3. Developments

Developments concentrate on two topics:

- Development of a system concept including the selection of the main components as chiller, heat rejection unit, solar system and hydraulic components including the optimisation of these components if required.
- Development of evaluation and standardisation procedures for small solar cooling systems. This procedure will include the energetic characterisation of the system. The goal of this work package is the development of procedures for the energetic and economic evaluation of solar cooling

systems for different climatic conditions and load requirements in order to be able to predict the performance of these systems reliably and reproducibly. This procedure will give installers more security regarding the performance of small solar cooling systems.

3.1. Component development

The systems are basically planned around the adsorption Chiller ACS 08 of the company SorTech AG. This chiller has a nominal cooling capacity of 8kW with a Coefficient of Performance (COP) of 0.6. The nominal point is defined for the following operation temperatures (in/out): driving circuit: 72/65°C; heat rejection circuit 27/32°C and chilled water circuit 18/15°C. As a second option the machine ACS 15 with nominal capacity of 15kW and a COP of 0.6 at the same operation conditions is available. Both machines can be operated with temperatures down to 60°C, although with reduced performance.

The solar system is provided by the company Solvis GmbH & Co. KG. The solar system is designed to provide domestic hot water, support for the heating system in winter and to drive the chiller when cooling is required. The solar system is modified by Solvis in order to be optimised for these three functions. The planned modifications include:

- A new loading device for the storage which is able to handle the large flow rates of the cooling system in the return line of the driving circuit without destroying the stratification of the storage
- A pre-assembled hydraulic switching unit to connect the hydraulic circuits of the chiller to the rest of the system components. This unit includes pumps, valves sensors, the control unit and all necessary service connection. The switching unit is pre-assembled in the factory and delivered to the installer. It eases the installation task and reduces the risk of wrong dimensioned pumps and valves. No further planning of the complex hydraulics is necessary any more.
- Adaptation of the system controller to include the solar cooling function. This includes the control of the chiller, the heat rejection, the chilled water circuit and the solar system. .

Installed systems [1],[2] have shown, that the efficiency of the heat rejection circuit and system is essential to achieve high efficiencies for the whole system. On the other hand wet cooling towers are not very popular for small capacity systems due to the high effort and costs for maintenance and water treatment required in some countries by law. These facts make wet cooling towers almost unviable in many countries for small systems. Thus only dry cooling towers seem to be an option, unless alternative solutions like ground heat exchangers, boreholes or other heat sinks are available. Although in this project we will decide on the best heat rejection option for each application, as a standard the dry cooling tower RCS08 and RCS15 from SorTech will be considered. These units are optimised dry coolers using EC-motors for the fans, a spraying option for very hot days and a control adapted to the periodic cycle characteristic of the adsorption chiller. This cooler will be further optimised working on:

- The reduction of the pressure losses on the fluid and air side through constructive optimisations
- Reduction of the electricity needs through the intelligent use of the spraying option in combination with the operation of the chiller
- Control of the flow rate in the heat rejection circuit, especially in part load operation of the chiller
- Analysis of different methods to protect the heat rejection unit from freezing taking into account the climatic conditions of the installation.

Further, alternative solutions like ground heat exchangers, boreholes and wet cooling towers will be evaluated regarding energetic and economic performance.

4. Monitoring and evaluation concept

A generally recognized, standardised and accepted procedure for the evaluation of solar cooling systems that can also be used to predict the performance as it is available for conventional heaters and heat pumps is not available yet. Although a sophisticated and general evaluation procedure was developed in the frame of the IEA-SHC Task 38 'Solar Air-Conditioning and Refrigeration' [3,][4], this procedure is not suitable to predict the performance of new systems and components in different climates and load conditions. Further, as solar cooling systems are alternatives to conventional systems any performance evaluation has to be carried out in comparison to the performance of a well defined reference system. Only in this way energetic and environmental benefits in terms of primary energy and CO_2 savings of the solar cooling system in comparison to the conventional solution can be calculated. Such a procedure will be developed in the frame of the project.

To have the data basis for this task, a standardized monitoring equipment has been developed for the field test systems. The monitoring will allow a detailed evaluation of the whole system according to the procedure of the IEA-SHC Task 38 as well as a detailed performance evaluation of the key components. Particular attention is paid to the electricity consumption of the pumps and the heat rejection unit as these are the main electricity consumers which reduce the electric COP of the system. The data evaluation will give valuable information to improve and optimize the operation and control concepts. The monitoring system will also be used for the development of a failure detection procedure. In the final product only the essential sensors will be included in the system controller.

5. Load calculation

One general difficulty when planning solar cooling systems is the appropriate dimensioning of the system, specially the choice of the chilling power taking into account the building characteristics and its use. A calculation of the cooling load is thus essential. Simple estimation based e.g. on the German recommendation VDI 2078 is a first, generally accepted procedure, but is often not sufficient for solar cooling systems. This procedure focuses on peak demand and less on the distribution of the load over the day and year. The result can be a system that is too large, operates often in part load and thus is too expensive and not very efficient. Especially the high costs will discourage some potential customers. For conventional systems this dimensioning is not as critical as the main costs are the operation costs and not the investment costs, part load operation, although also not optimal, is .accepted. For solar cooling on the other hand the distribution of the load and its matching with the solar resource is crucial for the right sizing of the system. In order to overcome this problem, an easy to use load calculation tool was developed and is being tested in the project. It is based on a simple building model with input values that in most cases can be easily provided by the building owner or user. Reasonable default values can be chosen if no real data is available. In a first step, the program calculates hourly heating and cooling demand curves which gives the planner an idea of the building loads. In a second step supposing constant driving temperatures and using the models for the chillers and the heat rejection units a mapping of the possible coverage of the hourly loads by the thermally driven chiller is calculated. In addition, the heat required by the chiller to produce the required cold is calculated giving an hourly heat demand curve for the whole year for heating and cooling purposes. This file can be further used to calculate the size of the solar system with the standard simulation packages. As only an integer multiple of chillers can be chosen, the coverage results also gives an indication about the necessary size of the back-up system if cooling has to be assured the whole time. In a future step the calculation of the solar system will be integrated into the program in order to have a tool that integrates the whole dimensioning procedure. The program will be kept simple on purpose in order to lower the barriers for its use and simplify the dimensioning process. It is not intended to substitute the more sophisticated simulation tools that are already on the market and are all in the process of including solar cooling modules.

6. Field test and participation opportunities

The developments mentioned in the previous sections will be accompanied by afield test of 10 compact solar cooling systems. In this field test the developed systems will be installed and operated at interested customers. The monitoring data will be used on the one hand to develop the evaluation procedure but also to monitor and optimise the systems operation.

As the field test systems should reflect real application cases we are looking for interested customers who would like to participate in this project. The type of application is broad: from domestic application in the residential area, over small offices, hotels and other commercial users many applications are possible. During the first project months it turned out that also larger capacities would be of interest on the market. Thus we extended the capacity range to a maximum of 60kW. This capacity will be achieved through an intelligent interconnection of several small machines. Each system will be individually dimensions and planned, but with the focus on the intended standardisation of the systems aimed in the project. A participation in the project SolCoolSys gives the customer the following advantages:

- A discount of around 20-25% on the solar cooling system
- A regular, free inspection and maintenance till the end of the project in December 2012
- A free monitoring and evaluation of the systems performance by Fraunhofer ISE till the end of the project in December 2012.
- An optimisation of the operation based on the operation results
- Harmonized components provided by reliable partners as a whole package

In return the customer has to assure the access to the system to the partners Solvis GmbH & Co. KG, SorTech AG and Fraunhofer ISE to carry out the required maintenance and optimisation work. Further, he has to agree to the publication of selected monitoring results. Finally, the systems should e installed in the years 2010 or 2011.

4. Conclusions

The project “SolCoolSys” carried out by the partners Solvis GmbH & Co KG, SorTech AG and Fraunhofer ISE aims to develop standardised small capacity solar cooling packages. The practical experience with these systems will be demonstrated with a field test of 10 systems installed at interested customers in Germany and abroad and will be accompanied by a monitoring and evaluation program carried out by Fraunhofer ISE. There is still the opportunity to participate in this field test as suitable customers for the installations are required.

5. References

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6. Acknowledgment

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