OPERATIONAL EXPERIENCES OF A TDHP SYSTEM FOR SOLAR COOLING AND HEATING OF A CANTEEN

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Abstract: Solar cooling systems offer the possibility to use primarily the renewable energy source solar heat for space cooling. Moreover, a solar cooling system can also be used to provide heat for space heating, in the case of working in heat pump mode. Besides theoretical investigations practical experience is required to evaluate the performance of solar cooling in the field. This document presents the main results from a solar cooling installation for canteen cooling, which is in operation since 2007. The data evaluation shows a seasonal electrical performance factor of 26.1 for space heating and 6.5 for space cooling. A seasonal thermal performance factor for cooling of 0.4 has been determined.

Key Words: adsorption chiller, solar cooling, operational experience, seasonal performance figures

1 INTRODUCTION

This report is about a thermally driven heat pump (TDHP) system operating in cooling as well as in heating mode. It is installed at the canteen of Fraunhofer ISE in Freiburg, Germany. This system is in operation since 2007. The main purpose is to provide air-conditioning for the kitchen of the canteen. If capacity is available the system supports the building main system with heat for the lobby. Depending on the inlet air temperature the operation between cooling and heating can switch during a day. For example, heat for space heating can be provided in the morning and afternoon while at noon the system switches to chill the kitchen.

The solar collector field of 22 m² aperture area is installed at the roof of the building and a hot water buffer storage of 2 m³ is installed in the basement. From the hot water buffer storage heat is taken to power the thermally driven heat pump system. Heat from the heating network of the ISE institute can be used as backup. Three bore holes are a part of the system. In cooling operation these holes reject waste heat to the ground while in heating operation heat is taken from the ground.

2 GENERAL DESCRIPTION OF THE SYSTEM

The ACS08 from the manufacturer Sortech AG is an adsorption type thermally driven heat pump. The rated chilling capacity in cooling operation at 15°C is about 8 kW, while the heating capacity in heating operation at 30°C is approx. 20 kW.

The 2 m² hot water storage with a stratified charger is only heated by the flat panel collector field. An external heat exchanger between the storage and collector field is used to separate the brine from the storage.

While the system is operating in cooling mode the rejected heat is pumped to three terrestrial probes, which are acting as a heat sink. Each of those heat probes is installed vertically into the ground as an 80 m long double-U-pipe. When the system is operating in heat pump mode the natural ground heat of approx. 13°C will be utilized as thermal output to preheat the air condition system of the foyer by an air-to-water heat exchanger.

An institute internal CHP-system is maintaining a heating network at 75°C. As backup the high temperature driving circuit can switch from the solar storage to this heat network, which is separated from the TDHP system via heat exchanger. No additional backup cooling or heating system is installed for the canteen kitchen.

3 HYDRONIC CONNECTION AND CONTROL STRATEGIES

3.1 Heating operation

During the heating season the use of heat from the buildings heating network dominates the driving heat supply for the TDHP. However, on sunny winter days sometimes the collectors provide heat for several hours at a temperature level which is sufficient to power the TDHP. The heat pump mode will be enabled in a time frame from 6:45 and 19:00 o'clock. To start the adsorption heat pump, the inlet temperature in the main air duct has to be between 14.5°C and 17.5°C (3 K hysteresis) due to the freeze protection of the chiller.

Figure 1 shows the hydronic connection of the system in heating operation. The cooling water loop is connected to the air handling unit to heat up fresh air for the foyer. Natural ground heat is taken via the bore hole. Heat from the solar collector or from the heating network as backup is used as hot water driving source.

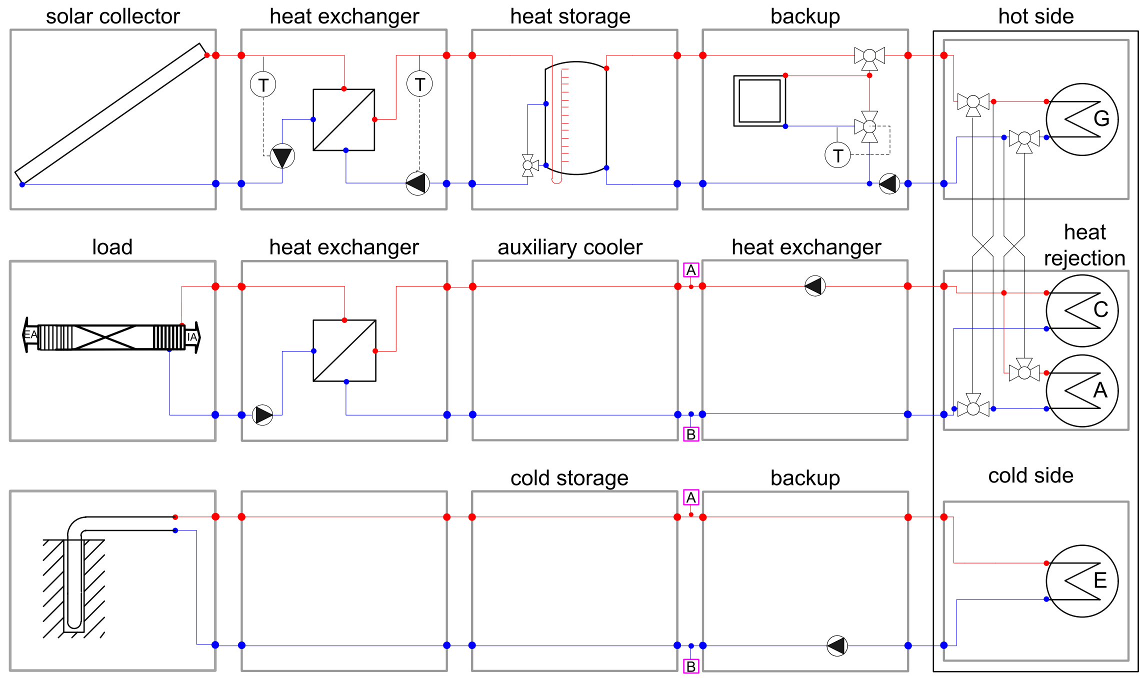

Figure 1: Hydronic representation of the system in heating operation

3.2 Cooling operation

During the summer the cooling process will be enabled in the time between 6:45 and 16:00 o'clock. The adsorption chiller is operating, when the inlet air temperature at the air-to-water heat exchanger exceeds 20°C (2 K hysteresis) and the air temperature in the kitchen is above 23°C (2 K hysteresis) at the same time.

The solar heat is used whenever the mean temperature in the upper part of the storage is above 65°C with a 5 K hysteresis for turning of solar heat supply. Figure 2 shows the hydronic representation of the system in cooling operation.

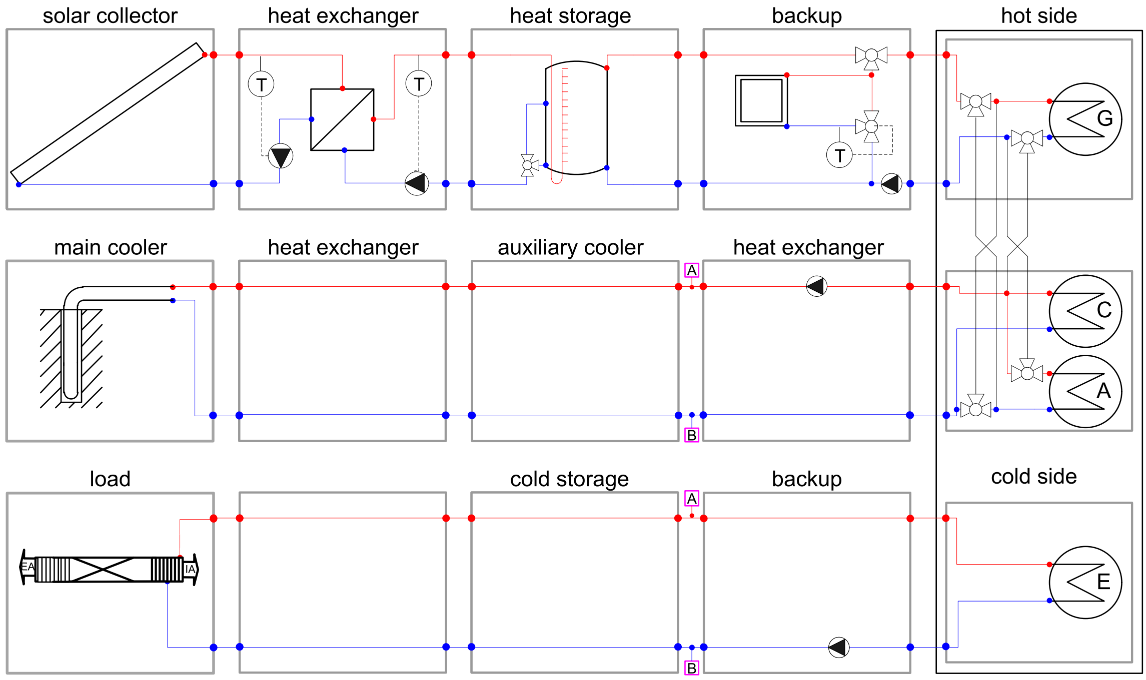

Figure 2: Hydronic representation of the system in cooling operation

The volume flows in the three circuits are kept constant and correspond to the nominal flows required by the chiller. Energy efficient pumps have been installed and the flow rate is set via the controller of the pumps.

In spring and autumn it may happen that the air temperature falls below 14.5°C in the mornings and thus the heating mode is activated, but later during the day temperatures in the canteen kitchen rise above the threshold for cooling operation. In these cases the system is operated in the heating mode first and later in the cooling mode.

4 MONITORING DATA AND PERFORMANCE EVALUATION

The system is under monitoring since 2007. Here, the data evaluation of the year 2009 is presented. Since the system could switch the operation mode on a daily basis the data are not presented in heating and cooling operation rather than in summer and winter period. However, intervals with heating and cooling operation are limited to several days per year in the transitional period between summer and winter.

4.1 Monitoring equipment

The monitoring system consists of internally integrating heat meters with paired Pt100 type temperature sensors. The integrator has a sampling rate of 1 s and calculates cumulated energy amounts, mean temperatures and powers. This internal sampling rate assures a correct collection of energy data for the highly dynamic temperature patterns characteristic of adsorption systems. The integrator and further temperature sensors are read out by a computer with a sampling rate of 15 s. The monitoring software further reduces these values to cumulated energies and mean temperatures which are stored within an interval of 5 minutes in the raw data measurement file. The storage interval can be set by the system operator and thus allows a flexible data management. The post processing of the raw data further reduces the values to hourly accumulated and mean values – depending on the quantity considered. For the hourly mean temperature values also a standard deviation is calculated in order to judge the stability of the temperature within the evaluated hour.

4.2 Cooling Operation

In cooling operation the system shows a seasonal thermal performance factor of 0.40. Thus, per unit of consumed heat 0.40 units of cold were produced. However, this seasonal value includes all disadvantageous operation states. As shown in Núñez (2008) the seasonal thermal performance factor has a value of 0.57 when neglecting the disadvantageous states. With a more sophisticated operation strategy the seasonal performance factor can be increased.

The seasonal electrical performance factor of the system is 6.5. This means that per unit of electricity consumed 6.5 units of cold were produced. The system still has potential to increase this parameter.

The following reasons are responsible for disadvantageous operation states:

- The temperature of the institutes heating network drops down from time to time. These fluctuations are not caused by TDHP system. The lower or fluctuating driving temperatures lead to a reduced seasonal performance factor of the TDHP.
- The performance calculation takes into account all starts and stops. Many such operation times occur which favour disadvantageous operation states. The short operation periods could partly be avoided by implementing a controller with forecasting strategy and the usage of chilled water buffer storage. Partly, the short operation times cannot be avoided if they belong to user behaviour.
- The design of the hydronic system was sized for a smaller cooling capacity chiller in the first place. However, the TDHP was replaced by a later system with higher capacity. While the installed hydraulic system couldn't been modified for the higher nominal flow rates of these later generations, the pumping capacity had to be increased to meet the higher flow rates. This fact led to a higher electricity consumption and thus to a lower seasonal electrical performance factor of the system.

4.3 Heating Operation

The seasonal thermal performance factor for heating operation is 1.24 and the seasonal electrical performance factor is 26.1. As shown in Núñez (2008) the seasonal thermal performance factor of the system in heating mode is 1.43 when neglecting disadvantageous states. The reduction of efficiency from 1.43 to 1.24 is caused by the same reasons as described above.

5 SUMMARY

The seasonal performance figures of a solar cooling system were presented. In cooling operation the seasonal electrical performance factor is 6.5 and the seasonal thermal energy efficiency ratio is 0.4, though can be increased to 0.57. In heating operation the seasonal electrical performance factor is 26.1 and the seasonal coefficient of performance is 1.24. It was already proven that the last factor can be increased when avoiding disadvantageous states.

The results show that a reliable operation of the solar cooling system is ensured. However, the heating network of the ISE institute used as backup shows irregular behaviours which affects the performance of the system. This raises the question how necessary operation conditions can be assured in applications with different needs to the supply system.

Moreover, frequent start/stops may be avoided with a better control strategy and will result in a better performance. It becomes clear, that a high potential lies in controller development. Future research should address this issue.

6 REFERENCE

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