

## OPTIMISATION POTENTIAL OF A LARGE SOLAR ADSORPTION COOLING PLANT

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### 1. INTRODUCTION

The innovative and highly energy efficient office building of the FESTO AG & Co. KG in Esslingen, with a useful floor area of 26.000 m<sup>2</sup> is cooled in summer by three 350 kW adsorption chillers (Mayekawa) and additionally through thermally activated bore piles of the buildings foundation. The cooling energy of the bore piles is provided to the thermally activated concrete ceilings of the building and the cooling energy of the adsorption chillers is mainly used to cool the air in the ventilation systems of the building. Since the building exists (2001), the driving heat for the chillers was provided by gas boilers and waste heat from the production facility. Since the end of 2007, a large solar plant, consisting of 1218 m<sup>2</sup> vacuum-tube collectors of the type CPC (Paradigma), contributes to heat production for cooling and heating. Figure 1 shows the integration of the solar thermal plant into the heating distribution system.

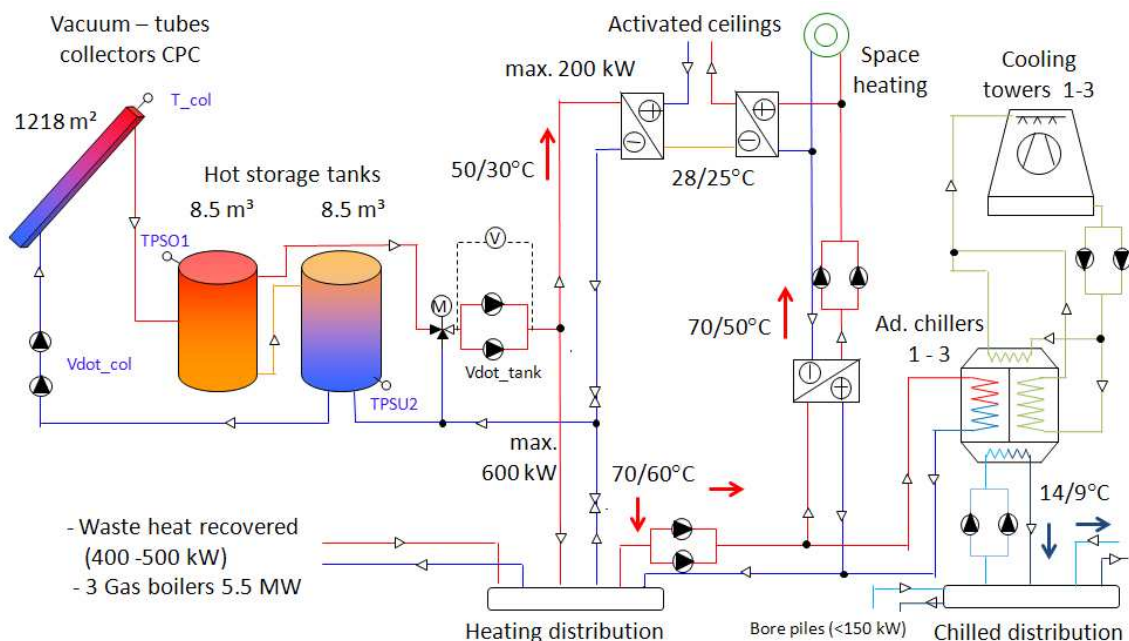


Figure 1: Hydraulic scheme of the solar adsorption cooling plant of FESTO

The objective of this work is the optimisation of this plant by the mean of a simulation tool. Based on the measurement data analysis [1], some optimisation points of the plant have been determined. Some simulation studies allow to propose an optimisation strategy. Additionally, the simulation model will be integrated for online simulation of the plant for errors detection.

## 2. MEASUREMENT DATA ANALYSIS

### 2.1. Electricity consumption

The analysis of the electricity consumption for the periods of June-November 2008 and Mai-July 2009 shows a large contribution of the cooling towers fans (figure 2) with an electrical COP between 2.7 and 3.5.

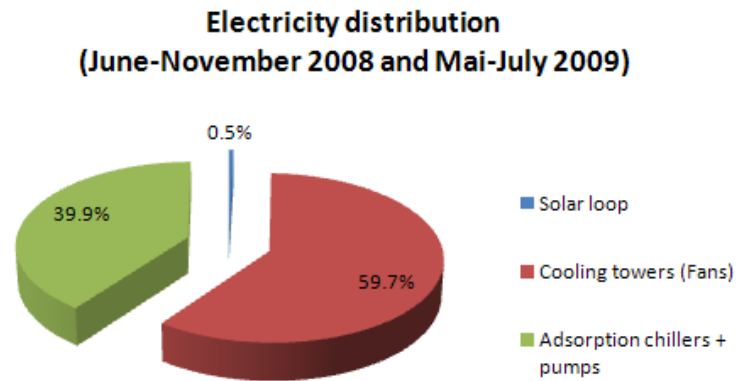


Figure 2: Contribution to electricity consumption of the FESTO plant

A better control of the cooling towers fans is very important to decrease the global electricity consumption and increase the electrical COP.

### 2.2. Adsorption chillers operation

The typical cooling load profile of the installation has been generated based on mean hourly values for different days in June and July 2009. Depending on the outside conditions, the amplitude of the cooling load differs but the profile does not change. There is a base load during the night with a peak load in the afternoon (figure 3).

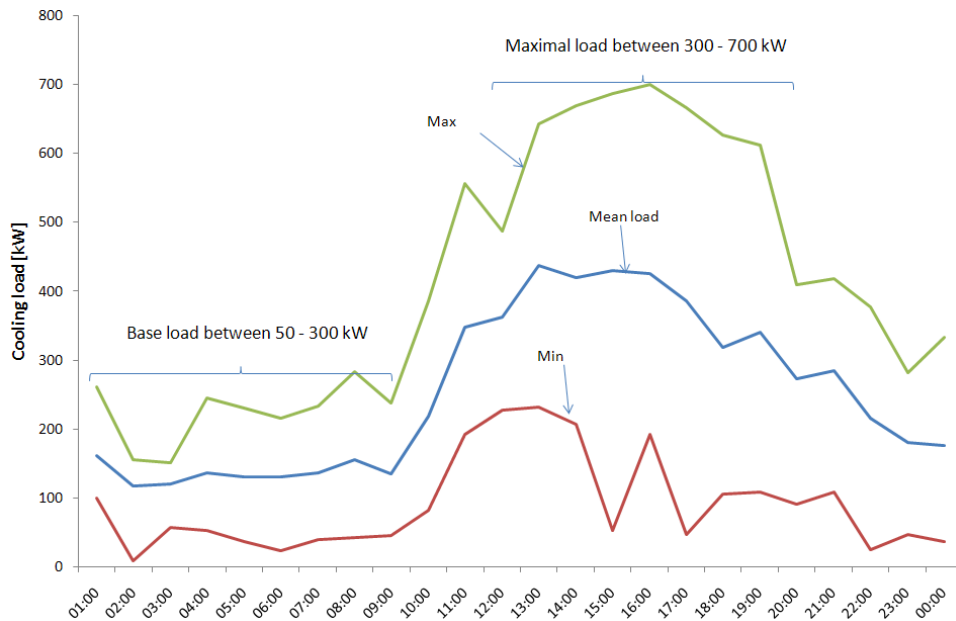


Figure 3: Typical daily mean cooling load profile and maximum/minimum values for each hours

### 3. SIMULATION MODEL

Dynamic simulation models of both solar thermal plant and adsorption chillers have been implemented in INSEL [2] and compared with measurement data [3-4]. Additionally, the model of Stabat et al. [5] for wet closed cooling tower has been implemented in order to study different control strategies of electricity consumption reduction. Figure 4 shows measured and simulated values (5 min mean values) of one of the cooling tower in wet regime (June 2008).

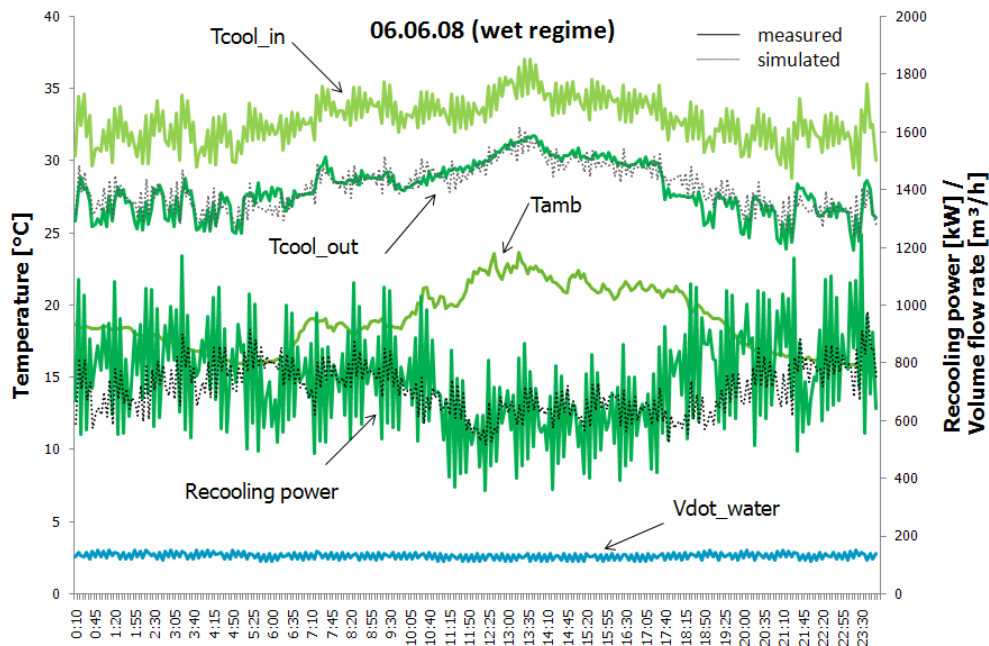


Figure 4: Measured and simulated values for one cooling tower in wet regime

The simulated results show relatively good agreements with the measured values and it has been used for simulation studies. The model gives also the possibility to simulate the cooling towers in dry regime.

### 4. OPTIMISATION

During the night, the “base cooling load” is usually covered by one or two of the adsorption chillers depending on the demand. Even during the night, the cooling towers fans are most of the time used at full power while the outside temperature is low. This is due to adsorption / desorption cycles of the chillers which create temperature peaks at the outlet water of the chillers. Figure 5 shows the measured performance of one of the adsorption chiller during the summer 2008 for typical operating conditions (mean hourly values).

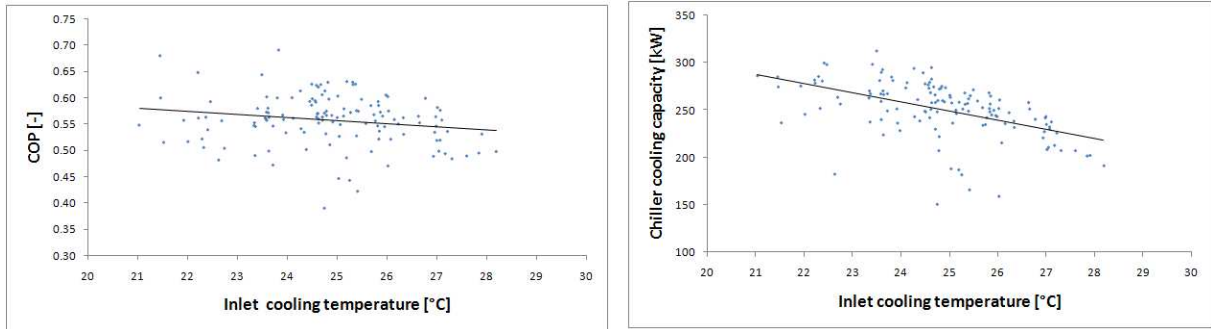


Figure 5: Performance of one of the adsorption chiller for typical operating conditions during the summer 2008. (Inlet hot water temperature of 68-70°C, inlet chilled temperature of 13-14°C and hot water volume flow around 40 m<sup>3</sup>/h).

Even if the cooling power is reduced when the recooling temperature increases, the COP is not dramatically affected. The idea is to use one of the chiller to cover the mean “base load” (around 150 kW) during the night with higher recooling temperature (by reducing the fan speed) in order to save electricity. A reduction of 50% of the fan speed induces a reduction of 85% in electricity consumption [6]. The typical summer night outdoor conditions in Stuttgart are around 14-16°C and 70-90% relative humidity. Figure 6 shows the simulated outlet temperatures of the cooling tower for different operating conditions with 50% of the nominal fan speed and a constant relative humidity of 80%.

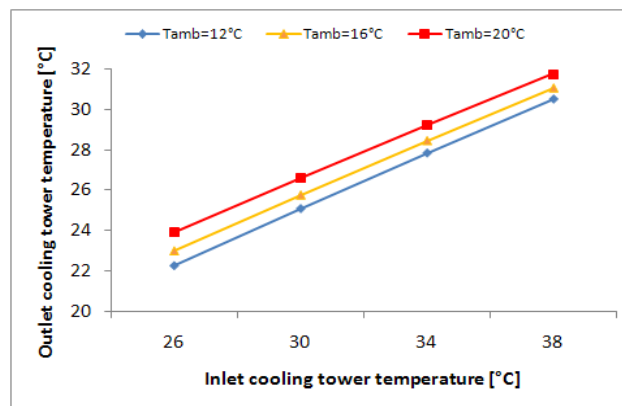


Figure 6: Simulated outlet cooling tower temperatures with 50% nominal fan speed

The problem of lower COP could be solved by increasing the cycle time of this chiller. This would also permits to reduce the number of cooling water temperature peaks and thus the fan speed necessary. The COP of the chiller for night operating conditions and different cycle times has been simulated (figure 7).

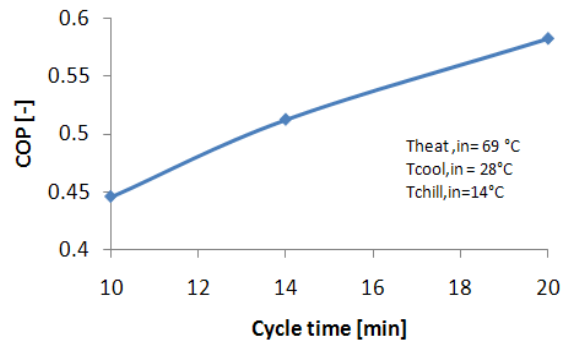


Figure 7: Simulated COP Vs Adsorption chiller cycle time (hot water volume flow rate of 40 m<sup>3</sup>/h)

## 5. ONLINE SIMULATION

The implementation of the model in the building control system of FESTO is currently under development. For such implementation, a communication structure has been developed for data acquisition and data communication between the building control system and our centre (figure 8). All measured data are written temporarily in an OPC server. The data acquisition is done with a program written in Labview. The communication with the simulation tool INSEL is realised by the mean of a Data Socket Server. Additionally, daily files (with the desired time resolution) can be generated for data analysis and simulation studies. The communication with the exterior is realised via Internet using VPN and FTP connections.

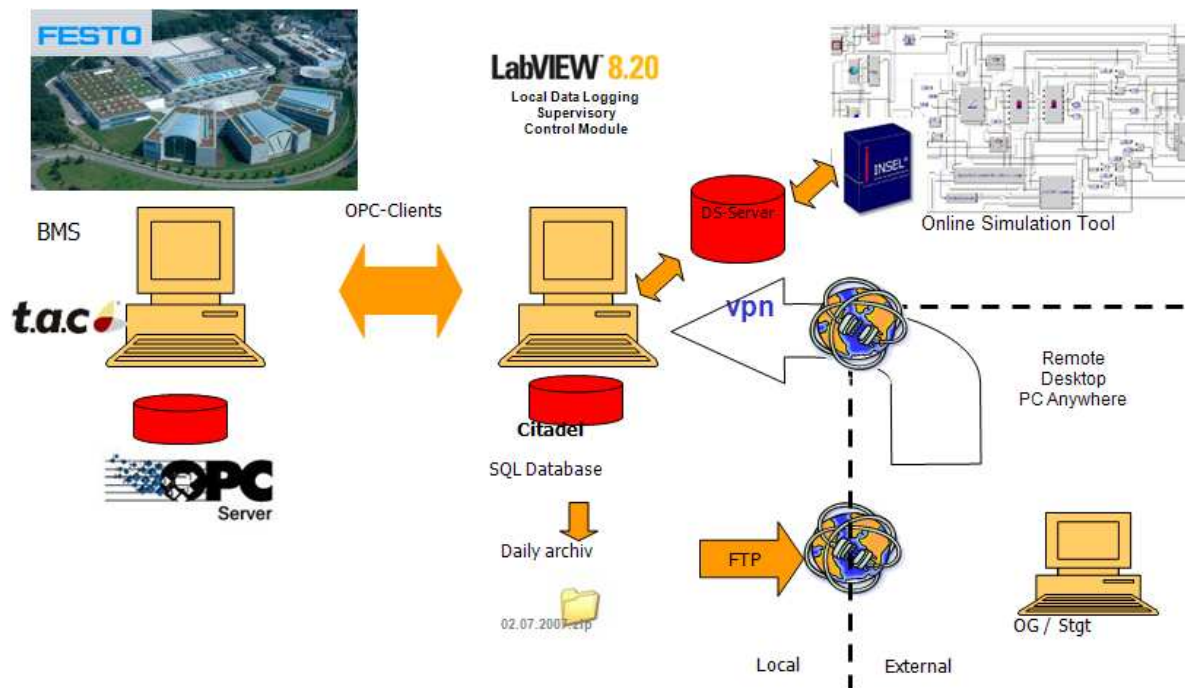


Figure 8: Data acquisition and communication for online simulation at FESTO

This communication structure will permit to perform online simulation and compare measurement with simulated values. For a too large deviation, an error message will be generated and sent automatically per Email to the users.

## 6. CONCLUSION

The data analysis shows a high electricity consumption due mainly to the fans of the cooling towers. This leads to a low electrical COP of the installation. In order to reduce the electricity consumption, a new night chillers operation has been proposed. This solution has to be studied in more details but it seems to be promised for enhancing the performance of the global system. Additionally, a data communication and acquisition structure is being developed for online simulation.

## 7. ACKNOWLEDGMENT

This work would not have been possible without the collaboration of the company FESTO AG and the University of Applied Sciences Offenburg who have provided all the measurement data necessary for this study. This work has been supported by the 6th European Union Research Program's Marie-Curie early stage research training network in "Advanced solar heating and cooling for buildings" - **SOLNET**. <http://cms.uni-kassel.de/index.php?id=2142>



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