Solar Heating and Cooling for the City of Gleisdorf
Optimisation of the Control Strategy

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Abstract

In June 2008 a system for solar thermal cooling and heating was put in operation in the Town Hall and Service Center of Gleisdorf, Austria. This was realised in the framework of the EU FP6 project HighCombi. Cooling energy is generated by an absorption chiller at one side and by a desiccant evaporative cooling (DEC) device at the other side. The whole installation is equipped with a monitoring system, capable to the IEA SHC Task38 Monitoring Tool. All measured values such as temperatures, humidities, flow rates, heat and electricity meters are logged in intervals of five minutes and are subsequently evaluated and analysed since October 2008. Based on the analysis of that measurement data, some optimisation measures on the control strategy were executed. This paper shows the influence of those optimisations on the operation performance of the system. The solar thermal driven cooling equipment, the absorption chiller and the DEC device were working as projected in general – not optimal operation conditions were caused by the conventional building equipment and appliances and the building structure itself.

1. Introduction

The system concept of the Service Center demonstration plant is shown in Figure 1. The provision of heat is realised at one side by the solar thermal collectors and on the other side by a district heating access. A solar thermal autonomous cooling operation is expected and district heating shall be active only during the heating period. The generated heat is stored in a hot tank all over the year. The heat for space heating and for the cooling applications is taken out of the storage.

Space heating is done via radiators and floor heating in the Town Hall and via ceiling elements in the Service Center. Space cooling distribution occurs via the same ceiling elements in the Service Center and via fan coils in the Town Hall. In the Town Hall ventilation is done manually via window opening. A central air ventilation system, performed as a DEC device with the possibility to generate an air flow depending cooling capacity supplies the Service Center with the hygienic air flow rate. Cold water is produced by an absorption cooling machine and is stored in a cold water tank. Recooling is done by means of an open wet cooling tower.

First year of monitoring showed good results of the solar heating part with electrical SPF_{el} (seasonal performance factor) of up to 82 kWh_{th}/kWh_{el} (as annual average), 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 could be investigated. First operation reports have already been published in [1], [2] and [3] since the beginning of monitoring in October 2008.

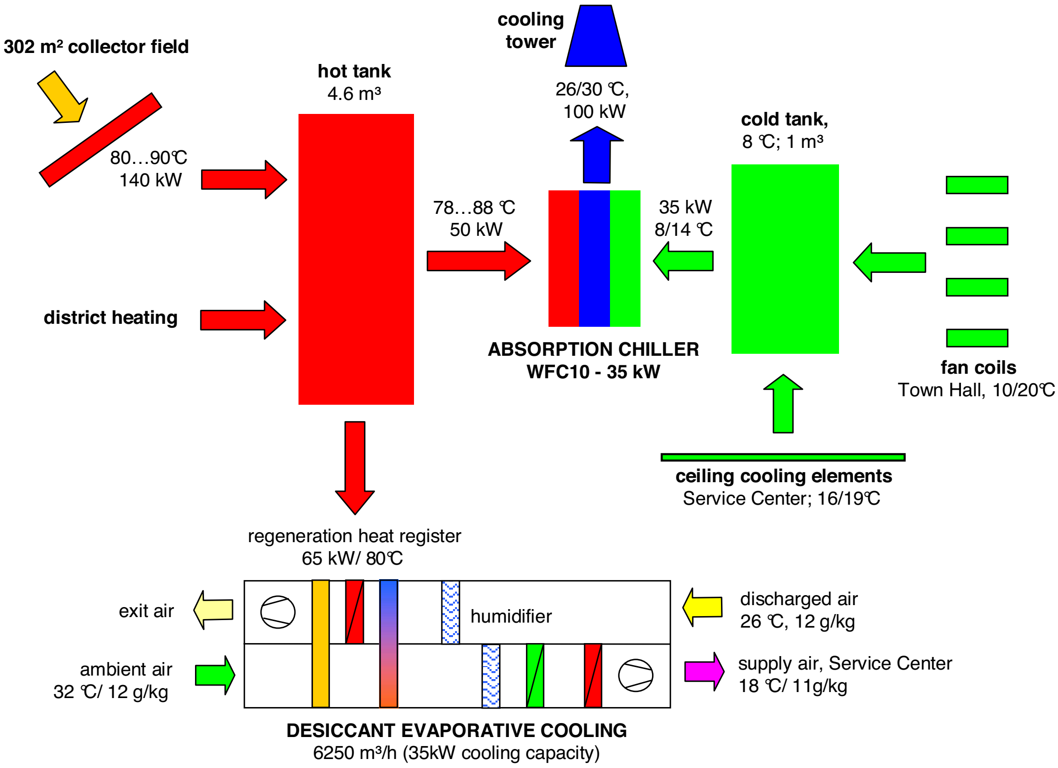

Fig. 1. Energy flow scheme of the entire system.

2. Solar Thermal System

The collectors installed on the roof of the Service Center are 134 m² of special high temperature flat plate collectors (HT) integrated with a teflon foil (Tilt angle: 20°, Azimuth: 30° W). The collectors on extra designed "Solar Trees" were installed in August 2009 (Tilt angle: 30°, Azimuth: 30° E) and are standard flat plate collectors (GV). Due to the different orientations (30° E and 30° W) solar energy can be gained more equal during the day. Both collector fields can be seen in Fig. 2.

Fig. 2. In the foreground 4 Solar Trees and 1 PV tree, behind the Service Center with roof collectors and in the background the Town Hall (source: SOLID)

Fig. 3 shows some characteristic curves of the collectors. The axis of the abscissas shows the temperature difference of the collector to the ambient air and the axis of ordinates shows the collector efficiency. The diagram compares four collector efficiency curves according to test certificates and four measured points of efficiency. The measured efficiency is the quotient of the measured power in the secondary solar thermal loop and the solar irradiation on the adequate collector area (both are five minutes average values). The collector efficiency curves were calculated with the characteristic values of the collectors, shown in Table 1.

Both curves GV- and HT 756 W/m^2 were calculated with the average solar irradiation of the measured points on the 11.02.2009 and the 22.02.2010. The average solar irradiation from the 08.06.2009 and the 09.06.2010 was used to calculate the curves GV- and HT 954 W/m^2. It can be seen that the measured efficiencies of the solar collector loop match quiet good to the collector efficiency according to test certificates.

Table 1. Characteristic values of both collectors.

	GV	HT
η_0	0.814	0.806
a_1	3.600	2.580
a_2	0.017	0.009
Q_{sol}	756/954 W/m^2	

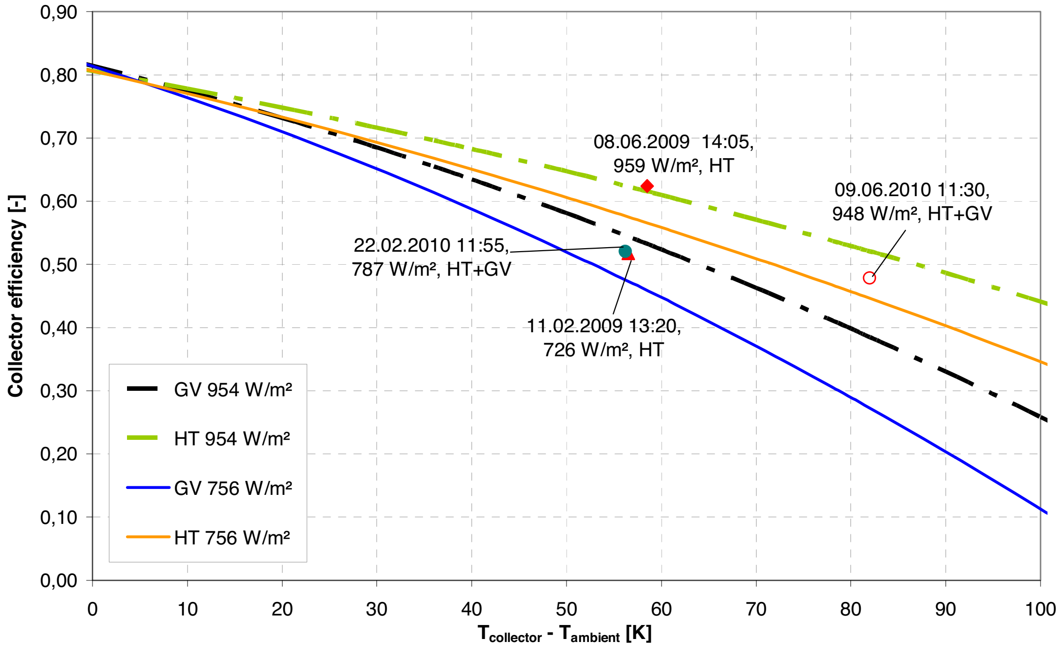

Fig. 3. Collector efficiencies.

3. Absorption Chiller

A YAZAKI WFC-SC10 absorption chiller with a nominal thermal coefficient of performance (COP_{th}) of 0.7 and a nominal cooling capacity of 35 kW produces cold water with a temperature of 7 °C. The generator efforts 50 kW thermal energy and the capacity of the used wet cooling tower is 100 kW. The used working fluid pair in the chiller is water as refrigant and lithium-bromide as solvent. The produced cold water is stored in a 1 m^3 cold storage.

The realized flow rate of 4.8 m^3/h in the generator cycle is 55 % of the nominal flow rate, indicated by the manufacturer. Due to that, the generated cooling capacity decreases for 14 % compared to the possible nominal cooling capacity. At a flow temperature of 82 °C a temperature difference of 9 K is resulting, instead of 5 K pointed from the manufacturer. This bigger temperature difference follows a reduced flow rate with the advantage of a lower electricity consumption of the generator cycle pump.

Fig. 4 shows the operation performance of the absorption chiller on the 18.08.2009 (active heat backup via district heating). Between 18:40 and 20:30 the chiller showed a steady state operation performance. At 20:00 the generator flow temperature (T_AKM_AustreiberVL) was 82 °C and the generator return temperature (T_AKM_AustreiberRL) was 73 °C. The recooling cycle temperatures was 32 °C for the entry in the cooling tower (T_AKM_Kondensator_RL_bzw_T_Kühlturm_VL), 27 °C for the exit of the cooling tower (T_Kühlturm_RL) and 29 °C for the entry into the chiller (T_AKM_-Kondensator_VL). The cold water flow temperature (T_AKM_KaltwasserVL) was 7 °C and the return (T_AKM_KaltwasserRL) was 13 °C. The generated cooling power (P_AKM_Kälte) of 23 kW and the generator power (P_AKMAustr) of 47 kW are resulting in a COP$_{th}$ of 0.49.

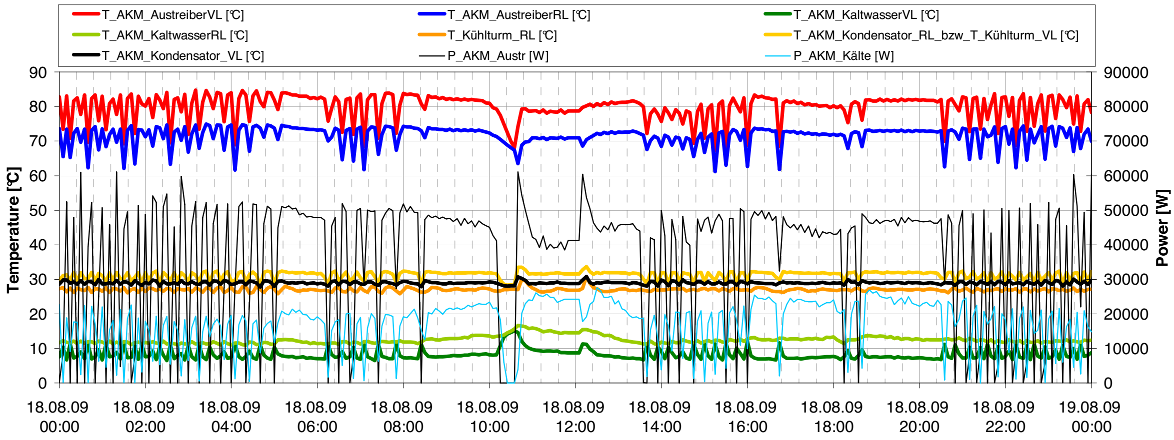

Fig. 4. Operation performance of the absorption chiller at 18.08.2009.

It is obvious that the chiller was active the whole day due to the active heat back up but with a relative often stop-and-go operation at the 18.08.2009. This happened nearly every day in 2009. The reason for that was found in a mistake in the control program of the building itself. This mistake resulted in almost closed control valves in the ceiling cooling element cycles most of the time, which naturally reduced dramatically the cold water flow and therefore only very reduced cooling of the office rooms was possible (resulting in high room temperatures). If the cooling load is “artificially” reduced that much, then of course there is no need for cold production of the chiller leading to this stop-and-go behaviour.

In Fig. 5 the average valve position of all control valves is shown. Since 0% means the valve is closed, it can be observed that most of the time the valves are in average in quite closed positions. When the ambient temperature was rising above 28 °C, it could be noticed that the average valve position was decreasing. In times with an increasing cooling load (ambient temperature, irradiation), the control valves reduced the cooling capacity of the ceiling cooling elements. For the cooling period in 2010 the control unit of the office building was reprogrammed and much better performance of the system is expected.

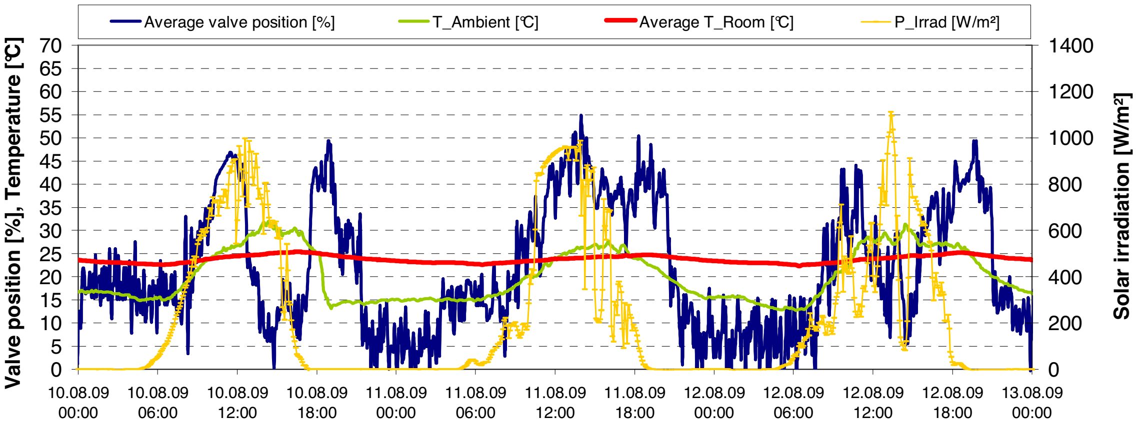

Fig. 5. Average control valve positions in relation to ambient temperature, solar irradiation and average of the 23 office room temperatures in 2009.

Fig. 6 shows a steady state operation performance of the chiller on 15.07.2010 where solar autonomous cooling was realised. The chiller started at 09:35 due to the available temperature of 82 °C in the upper part of the heat storage and operated as long as the temperature in the storage decreased beyond 78 °C at 16:40. There was no stop-and-go operation inbetween. The generator flow temperature was limited to 88 °C and was reached at 13:20, the return temperature is 11 K lower. At 10:30 the generator temperature difference was 9 K. The flow temperature of the recooling cycle into the cooling tower was 33 °C and the return was 29 °C during operation (set-temperature of 26 °C could not be reached due to higher ambient temperatures). At 15:00 the generator power was 59 kW and the cooling power was 33 kW resulting in a COP_{th} of 0.56. At 11:00 the generator power was 50 kW and the cooling power was 33 kW resulting in a COP_{th} of 0.66.

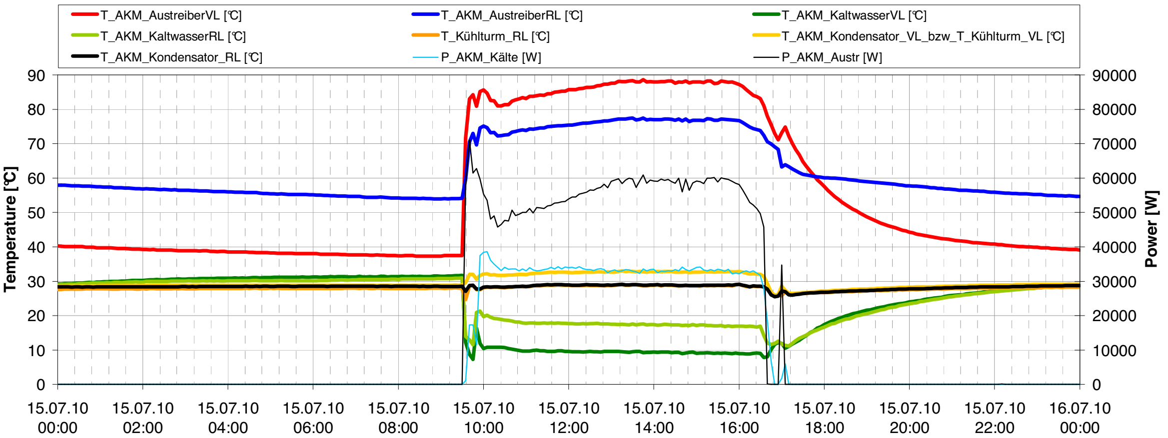

Fig. 6. Operation performance of the absorption chiller at 15.07.2010.

The cooling power is relative constant during operation but the generator power is increasing whereas the generated cold water temperature decreases and the generator temperature increases. The generated cold water temperature was at 10:30 11 °C and at 15:00 9 °C with both a temperature difference of 8 K. Note: On 18.08.2009 20:30 the generated cold water temperature was 7 °C with a temperature difference of 6 K, COP_{th} of 0.49.

This shows the huge influence of the produced cold water temperature on the COP_{th} which is much higher than the influence of the generator flow temperature.

The average SPF_{th} of April, May and June 2009 was 0.42 and the SPF_{el} was 3.85. For the same months in 2010 the SPF_{th} was 0.48 and the SPF_{el} was 4.97. The electrical SPF's do not include the electricity consumption of both solar cycle pumps.

The reason for the higher SPF_{th} and SPF_{el} in 2010 than in 2009 can be found in the higher average produced cold water temperature, the reduction of the set-recooling temperature from 29 °C to 26 °C and a higher generator flow temperature of 88°C. In 2009 the average generator flow temperature was maximum 84 °C due to the fact that the heat back up could not deliver a higher flow temperature.

Fig 7 shows the average valve position of all control valves in 2010. Compared to 2009 the average valve position does not decrease any more when the ambient temperature is rising.

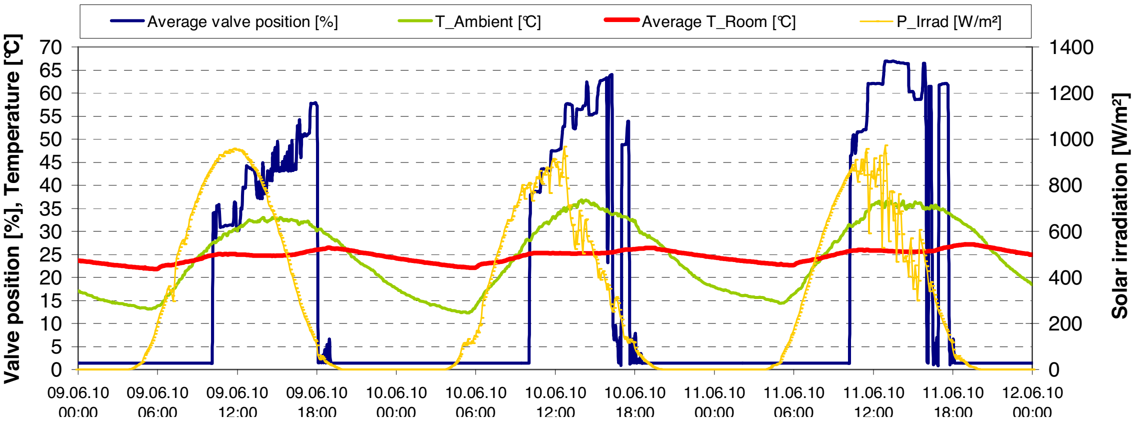

Fig. 7. Average control valve positions in relation to ambient temperature, solar irradiation and average of the 23 office room temperatures in 2010.

4. Desiccant Evaporative Cooling (DEC)

In Fig. 8 and Fig. 9 the temperatures of the supply air stream in the DEC unit are shown. The heights of the velocities show the operation of the supply air and the exhaust air ventilators (v_DEC_ZUL/ABL). On 18.08.2009 from 09:45 to 17:00 DEC operation was active when the temperature after the sorption wheel (T_DEC_ZUL_nach SR) was between 40 °C and 47 °C. Supply air temperatures (T_DEC_ZUL) of 20 °C to 22 °C were reached at maximum ambient temperatures (T_Aussen) of 32 °C. The trend of the average office room temperature (T_Büro) is also viewed in both line charts. "T_DEC_AUL" is the ambient air entering the ventilation device. "T_DEC_ZUL_nach WRG" is the air temperature after the heat recovery wheel. "T_Büro_ZUL" is the supply air temperature into the office rooms. Between the supply air temperature out of the ventilation device and the supply air temperature into the office rooms a cooling and a heating register are installed. On 30.06.2010 DEC operation takes place from 10:00 to 16:00. At a maximum ambient temperature of 34 °C a supply air temperature of 19 °C could be reached. The supply air temperature into the office rooms (T_Büro_ZUL) was 16 °C due to the active cooling register downstream. 2010 shows a better performance of the DEC than 2009. The lower generated supply air temperature of 19 °C at even higher ambient temperatures is caused by a revision of the control program of the DEC.

In Fig. 8 night ventilation is active from 00:00 till 02:15 and from 22:00 to 00:00. In Fig. 9 it is active from 00:00 to 06:00 and from 19:15 to 00:00. In 2009 both supply and exhaust air ventilators were active to generate the night ventilation. Due to several heat transfer effects (heat losses of the fan and technical room temperatures of above 30 °C) the sucked ambient air gets heated up from 14 °C to 24 °C at 02:00 and the average room temperature is still 23 °C. So the whole potential of the night ventilation with cold ambient air was lost. In 2010 the night ventilation strategy was changed. Only the exhaust air fan is active and supply air streams through automatically opened windows direct into the office rooms. With that strategy the whole potential of the cool air at night is effective. At 05:00 the ambient air temperature is 14 °C, so the supply air temperature (streaming through the windows) is also 14 °C, where the average room temperature is 22 °C at 06:00 in this case.

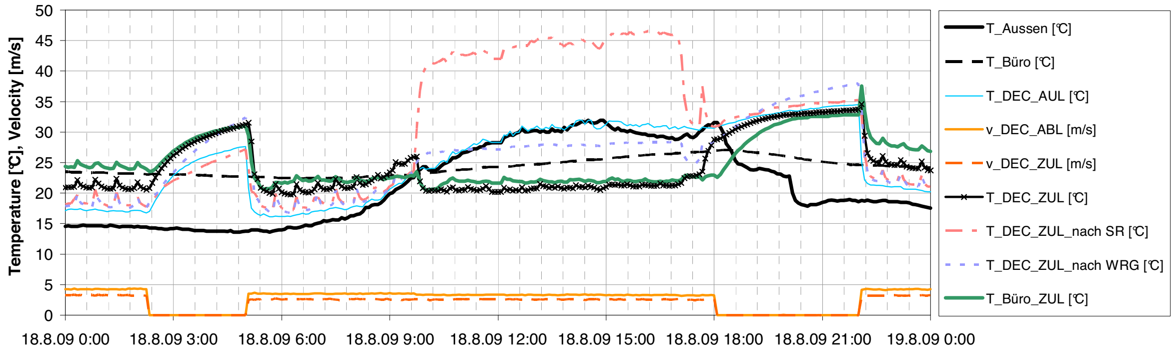

Fig. 8. Screenshot of the DEC unit on August 18th, 2009

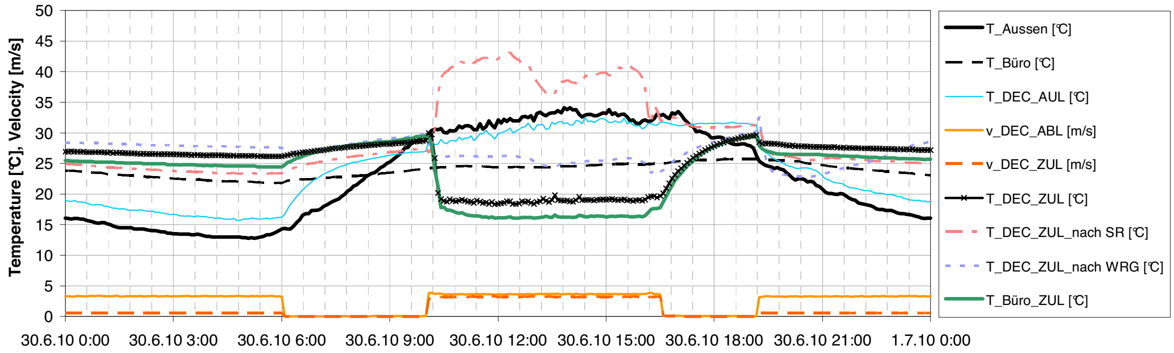

Fig. 9. Screenshot of the DEC unit on July 30th, 2010

A quite big electricity consumer for this DEC system is the **water treatment** equipment with nominal power of about 0.8 kW stationary consumption for a circulation pump and the UV-lamp for disinfection and further 0.8 kW occasionally for the osmosis filter when fresh water is filled into the system. In June and July 2009 this resulted in average to electricity consumption just for water treatment of about 25 kWh per day, whereas running the DEC system itself consumed about 108 kWh per day. For comparison: thermal energy used for regeneration of the sorption wheel in average was 176 kWh per day in the two months June and July.

Even in winter time the water treatment unit was in operation despite the fact that no water was needed because the humidification unit in the air handling unit was switched off. This resulted during the period December 08 to February 09 in water consumption of about 81 m³ and electricity consumption of about 1690 kWh. On November 20th, 2009 the controller of the water treatment unit was reprogrammed to minimum necessary activities, just to keep the components maintained as needed. Before the changes the electricity consumption was constant at around 800 W for running the UV-Lamp and the circulation pump for that. When the UV-Lamp got too warm the system cooled down by flushing the water to the drainage and refilling with fresh and cold water which caused the activity of the osmose filter with the intergrated high pressure pump resulting in a total power of up to about 1600 W electricity consumption.

After reprogramming in the months December 09 to February 2010 the water consumption reduced to about 6 m³ and electricity consumption to about 41 kWh. This means a reduction of 93% water consumption and 98% electricity consumption.

5. Conclusion

The realised optimisation measures were resulting in an improved steady state operation performance of the absorption chiller. The average SPF_{th} of April, May and June 2009 was 0.42 and the SPF_{el} was 3.85. For the same months in 2010 the SPF_{th} was 0.48 and the SPF_{el} was 4.97.

The operation performance of the DEC got better in 2010. In 2010 a supply air temperature of 19 °C could be reached at ambient temperatures of 34 °C compared to 22 °C generated supply air temperature at 32 °C ambient temperature in 2009.

Further the effect of the night ventilation could be maximised with the strategy to drive only the exhaust air fan to get direct fresh air through automatic open able windows with the advantage of the half electricity consumption of the fans.

The electricity and water consumption of the water treatment unit could be decreased by 93 % resp. 98 % due to reprogramming the control system in the last heating period.

Nevertheless there were further optimisation potentials detected. One is the delivery of the conditioned air to the right places in the Service Center. Actual the corridors are supplied with conditioned air directly. This air flow should be brought into the office rooms first where it would be more effective and further used to ventilate the corridors. Also the night ventilation could be advanced - the windows could be opened wider as done now to get a higher air flow. Also the operation-length of the night ventilation can be enlarged – depending on the ambient temperature and not on time schedule.

References

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