ENERGY PERFORMANCE IMPROVEMENTS OF A DEC SYSTEM DUE TO WET HEAT EXCHANGERS

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ABSTRACT

This work concerns an innovative desiccant and evaporative cooling (DEC) system for building air conditioning. The original system is an experimental DEC air handling unit installed at the Solar Laboratory of the University of Palermo and recently modified and updated. With the aim to increase the cooling effect due to water evaporation in the return air flow rate, the sensible heat exchanger was replaced with two cross flow flat plate heat exchangers installed in series, with continuous humidification of the secondary air flow. The new thermodynamic cycle is theoretically described and the realization of the real application is shown. Detailed operational data and energy performance indicators are presented and compared to the previous configuration.

INTRODUCTION

The layout of the original DEC system was a hybrid configuration with two additional auxiliary cooling coils fed by a conventional vapour compression chiller integrated in the DEC air handling cycle (Figure 1). One cooling coil (CC1) is used for pre-dehumidification of the outside air stream; the other coil (CC2) controls the air temperature if the desired supply temperature cannot be reached through the indirect evaporative cooling process.

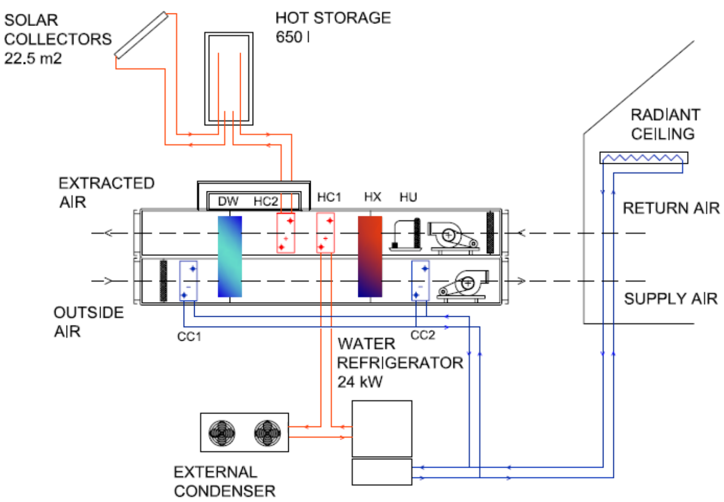

Figure 1: Layout of the previous DEC system

Another specific feature of the system is the use of part of the heat rejected by the refrigerator condenser to preheat regeneration airflow [1]. After two years of monitoring, it was observed that an optimization of the system could be possible.

THE NEW SYSTEM CONFIGURATION

The most important modification implemented in the AHU was to replace the rotating heat exchanger with two cross flow flat plate heat exchangers in series, in order to maximize the exploitation potential of evaporative cooling effect associated to the return air stream. Furthermore this intervention aimed to avoid problems of carry-over of water vapour from the return to the process air side inside of the rotating heat exchanger. The new air-to-air heat exchangers are equipped with spray nozzles, basin and recirculation pump. The package humidifier in the return air stream has been eliminated because some initial tests evidenced that the return air is sufficiently humidified by the wetted surface inside the heat exchanger.
The desiccant wheel is now regenerated by external air, which is heated by the two heating coils (HC1 and HC2). This causes the use an additional fan, but at the same time, the regeneration air flow can be modulated according to specific control strategy independently by the return air flow. That permits a reduction of the electricity consumption of the fans in winter operation and ventilation mode.
Figure 2 shows the modified DEC AHU and the process of air treatment on the psychrometric chart.

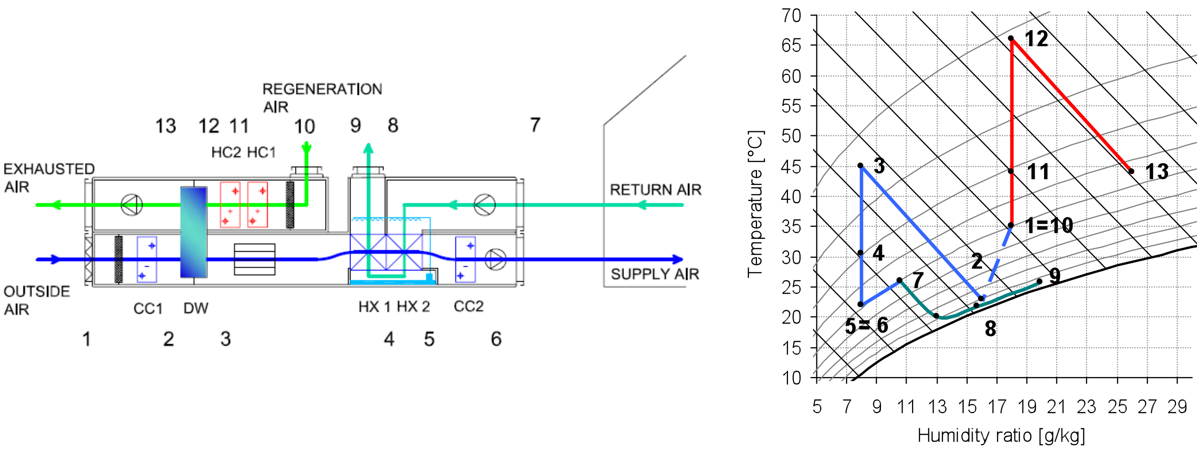

Figure 2: New DEC system configuration with wet heat exchangers

The control strategy of the system was slightly modified (Figure 3). In principle it works as before with three different operation modes in summer (1: indirect evaporative cooling, 2: desiccant evaporative cooling, 3: auxiliary cooling) and two in winter (-1: heat recovery, -2: active heating). If no thermal air treatment is necessary, the system works in free ventilation (mode 0).

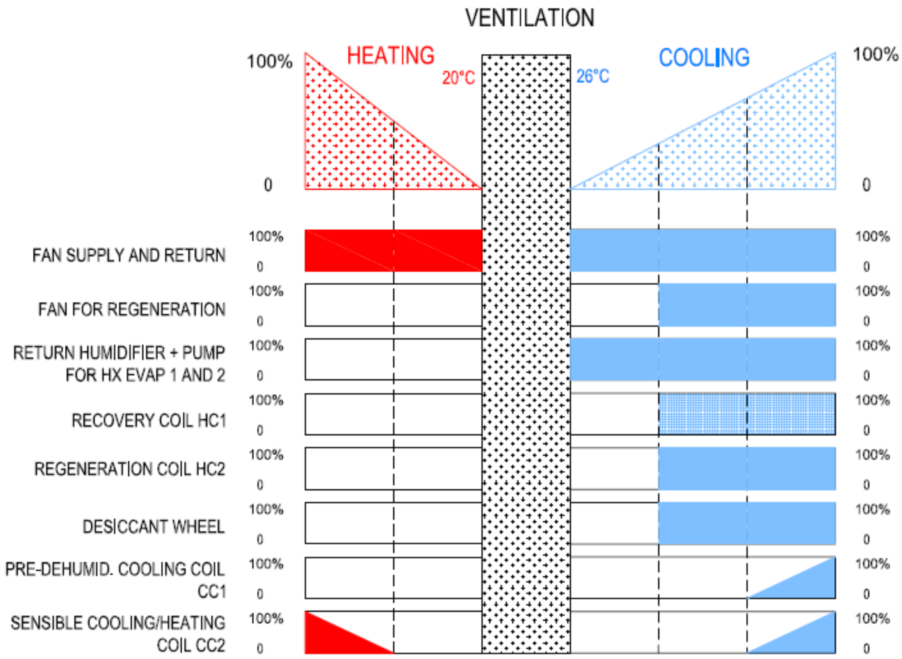

Figure 3: Control strategy for the updated DEC configuration with wet heat exchangers – the x-axis shows the increasing cooling/heating power

The new control strategy differs from the previous one for the following aspects:

- The regeneration fan can be now controlled independently of the fan for the process air and can be switched off in ventilation mode (MODE = 0) and indirect evaporative cooling mode (MODE = 1).
- The new recirculation pump used in the wet heat exchangers is activated in MODES 2 and 3 and is off in all other operation modes.
- No air by–pass across the desiccant wheel is used

IMPROVEMENT OF PERFORMANCE OF THE NEW CONFIGURATION

Monitoring results in the first year of operation have shown a very satisfying exploitation of the evaporative cooling effect. The process air temperatures measured at the outlet from the heat exchanger were notably decreased, reducing the cooling power required from the auxiliary coil CC2. This is due to the fact that secondary air is kept near to the saturation line during the whole heat exchange process.

Daily results

In Figure 4, Cooling Power of the whole AHU and the DEC-process and the electrical COP are shown, defined as:

$$P_{DEC} = P_{AHU} - P_{Aux}$$

$$COP_{el}AHU = \frac{P_{AHU}}{P_{el\,Fan} + P_{el\,pumpsAHU} + P_{el\,cool\,Aux}}$$

The DEC cooling energy amounts to 80% of the total delivered for the considered day. A mean electrical COP of 3.65 is reached.

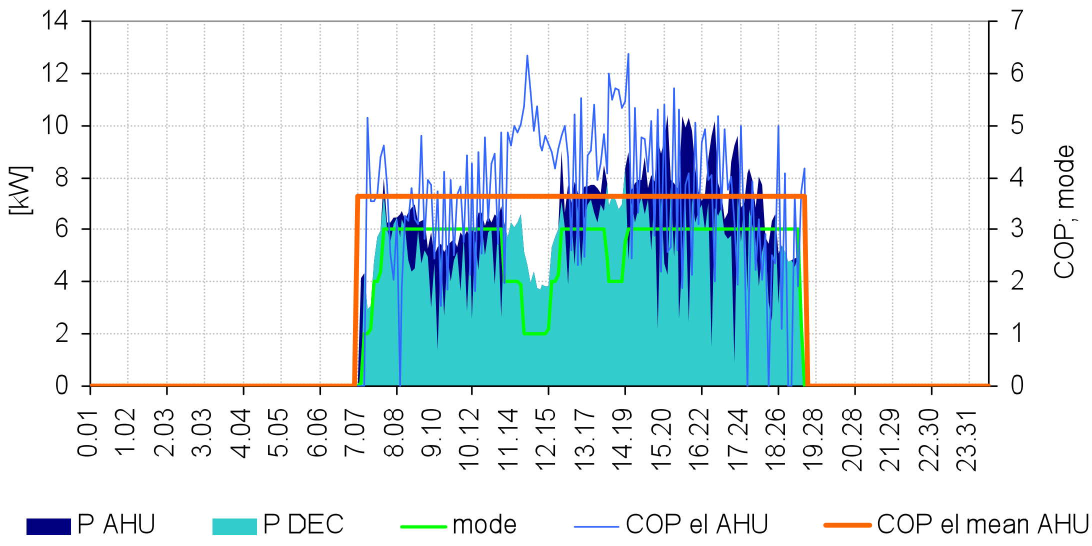

Figure 4: Cooling power and electrical COP of the AHU, 3 July 2011

Figure 5 shows the cooling power and the inlet/outlet-temperatures measured in the heat exchangers.

During the peak power operation, process air temperature are lowered from 43°C to 23°C. A minimum supply temperature of 21°C was registered whereas the set-point for supply condition (22°C) is almost reached.

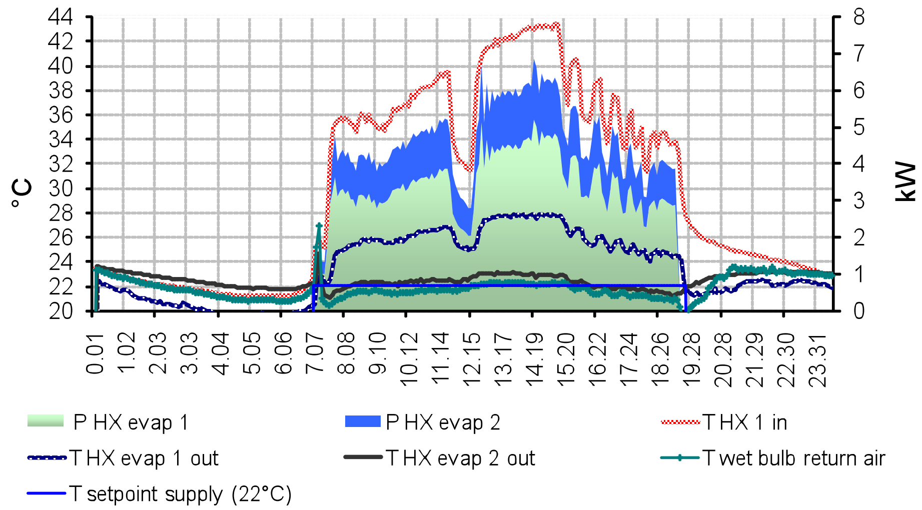

Figure 5: Cooling power and temperatures of the two wet heat exchangers, 3 July 2011

Monthly and seasonal results

The monitored time period of the new configuration regards Aug, Sept 2010, June, July, 2011. Results obtained have given good long-time energy performance compared with the previous configuration. It can be noted in Figure 6 that 69% of the cooling power delivered from the AHU was provided by the DEC-process whereas in the previous configuration it amounted to 53%.

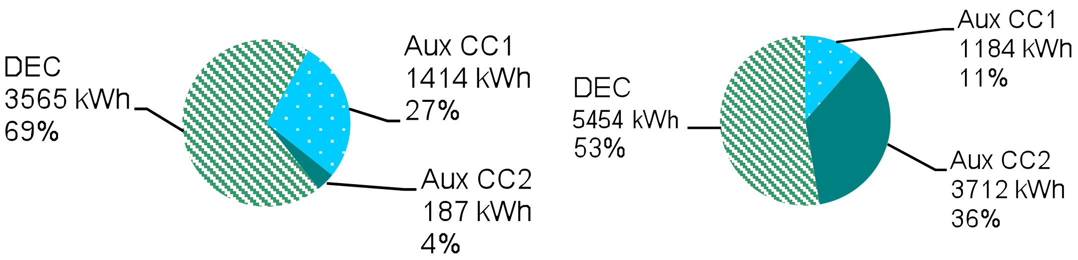

Figure 6: Total seasonal Cooling Energy produced by the new (left) and the previous (right) DEC AHU

For more detailed considerations of single months, meteorological conditions must be taken into account. As shown in Figure 7, the intervention of the second cooling coil in the new configuration is notably decreased. The higher contribution of the first cooling coil CC1 in July 2011 was due to higher external air humidity (mean value registered in 2011 was 18.7 g/kg whereas 13.7 g/kg in 2008).

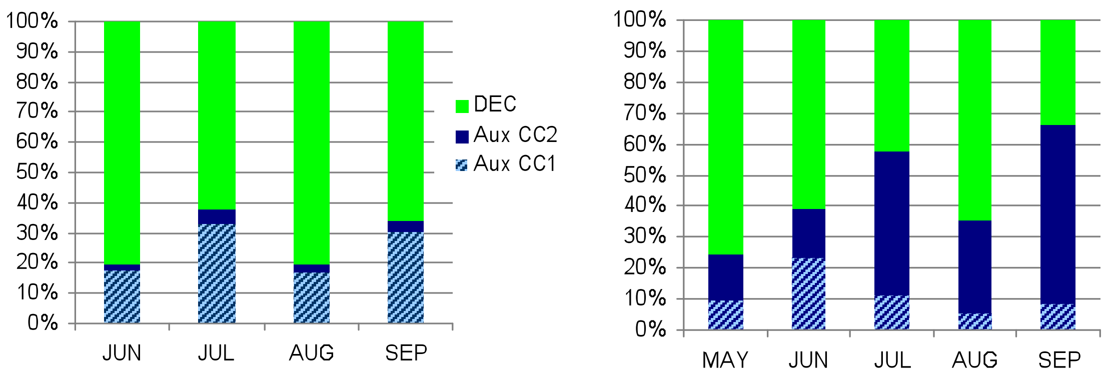

Figure 7: Monthly division of delivered cooling power in the DEC AHU with evaporative heat exchanger (left) and in the DEC AHU with sensible heat exchanger (right)

Finally, Primary Energy Savings of the DEC-system related to a conventional AHU have been calculated in accordance with the Unified Monitoring Procedure developed in the framework of Task 38 IEA [2].

The average PE-saving of 53.7% in summer operation has been reached (PE-saving in the previous configuration was 49.2%). This value was calculated considering the monthly cooling energy delivered as weighting factor.

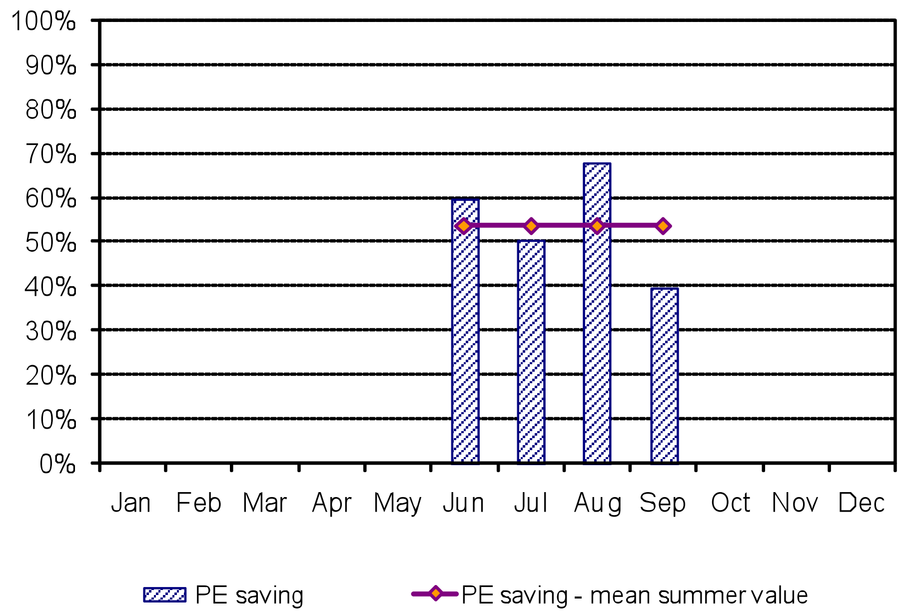

Figure 8: Primary Energy Saving and Solar Fraction in the DEC AHU with evaporative heat exchanger

Conclusion

Results obtained in the first season of cooling operation are encouraging, showing that DEC systems can very much benefit from the use of wet heat exchangers to cool down sensibly the air stream after the adsorption process in the desiccant wheel. Pressure drops in the AHU can also be reduced thanks to the new configuration and control of the regeneration air flow rate.

Consequently auxiliary cooling energy and electricity consumption of AHU can sensibly be reduced and good values of electrical COP can be reached.

References

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