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New absorption chiller and control strategy for the solar assisted cooling system at the German federal environment agency

Jan Albers[*]

Technische Universität Berlin, Institute of Energy Engineering, Sek. KT 2, Marchstraße 18, 10587 Berlin, Germany

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ABSTRACT

Typically the cooling capacity of absorption chillers is controlled by adjusting the driving hot water temperature according to the load. Meanwhile the cooling water temperature is controlled to a constant set value. In order to increase the solar cooling fraction and/or to decrease the operating costs of solar assisted cooling systems (SAC-systems) a new control strategy has been developed which controls hot and cooling water temperature simultaneously. Hereby the specific cost of cold – generated from solar or conventional heat – can be reduced. The basic concept of the strategy is explained and results are shown for the SAC-system at the Federal Environment Agency in Dessau, Germany. Here a recently developed absorption chiller is now used instead of a former adsorption chiller. With the new absorption chiller and the control strategy the seasonal energy efficiency ratio SEER is above 0.75, electric efficiency is 35% higher and water consumption is reduced by 70%.

Nouveau refroidisseur à absorption et stratégie de régulation pour le système de refroidissement fonctionnant en partie à l'énergie solaire à l'Agence Fédérale Allemande pour l'environnement

Mots clés : Refroidisseur à absorption ; Refroidisseur à adsorption ; Surveillance ; Prix du froid ; Stratégie de régulation

1. Introduction

The Federal Environment Agency (Umweltbundesamt, UBA) relocated its head office from Berlin to Dessau in 2005. The total energy demand of the newly erected building is in between a low energy house and a passive house. By means of an air ground heat exchanger the office rooms do not need any additional air conditioning. But for the high cooling loads of a

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[*] Tel.: +49 (0)30 314 25314; fax: +49 (0)30 314 22253.
E-mail address: jan.albers@tu-berlin.de.

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Nomenclature

A	heat exchange surface, m^2
B	Dühring parameter, –
C	cost, €
COP	coefficient of performance, kW kW^{-1}
CTC	Compression-type chiller
c_p	specific heat capacity, kJ kg^{-1} K^{-1}
D_{sol}	solar fraction
e	specific electricity consumption, kJ kJ^{-1}
E	energy, kW h
f	friction factor
$\dot{m}$	mass flow rate, kg s^{-1}
P	dimensionless temperature glide, K
P	electric power, kW
p	price of energy, € kW^{-1} h^{-1}
$\dot{Q}$	heat flow rate, kW
$\dot{q}$	specific heat flow rate, kW m^{-2}
q	specific thermal Energy, kW h m^{-2}
r	loss parameter (in characteristic equation) kW
R	heat capacity flow rate ratio
RHD	reject heat device
s	slope parameter (in characteristic equation), kW K^{-1}
SAC	solar assisted cooling
SEER	seasonal energy efficiency ratio, kJ kJ^{-1}
t	temperature, °C
TDC	thermally driven chiller
V	volume, m^3
$\dot{V}$	volume flow rate m^3 s^{-1}
$\dot{W}$	heat capacity flow rate kW K^{-1}

Greek symbols

$\Delta\Delta t$	characteristic temperature difference, K
γ	control signal or dimensionless flow rate
ρ	density, kg m^{-3}
τ	time, s

Sub- and superscripts

*	modified
A	absorber
amb	ambient
C	condenser
cold	related to cold energy
conv	conventional
D	desorber
E	evaporator
el	related to electrical energy
fric	frictional
FW	district heating
gh	global horizontal
i, o	inlet, outlet
K	solar collector
KS	cold storage
mat	material
min	minimum
op	operating
opt	optimal
PS	buffer storage
RHD	reject heat device
set	set value
sol	solar
std	standard
TDC	thermally driven chiller
th	related to thermal energy
wet	related to humidifier in RDH
X	alphabetic placeholder for component

building integrated IT-centre, teaching rooms and the lecture hall additional cold generation was necessary. With the ambition of primary energy savings a solar-assisted cooling system (SAC-system) has been designed, which used an adsorption chiller at first.

Recently Henning and Döll (2012) showed in a simulation survey that primary energy savings of up to 80% can be realised by solar heating and cooling systems when the conditions are favourable. Marc et al. (2010) report about such a system with high solar irradiation (i.e. mean daily sum $q_{gh} \approx 6$ kW h m^{-2} d^{-1} over four month), good coherence of irradiation and cooling load and no need for back-up heat. Although the main goal to cool classrooms without any backup system during the occupancy period was reached a large optimisation potential was identified in the electricity demand for cooling tower fan and cooling water supply pump. Despite of the favourable conditions it turned out that the electrical efficiency of this SAC-system with $COP_{el} = \dot{Q}_E / \sum P_{el} \approx 1.0$ to 1.7 is in the same range as for a conventional cooling system. In addition Sparber et al. (2009) evaluated the primary energy efficiency of several realised SAC-systems within the IEA TASK 38 (International Energy Agency Solar Heating and Cooling Program). They concluded that primary energy saving is not achieved by all systems, that overall electricity consumption and thermal back-up energy are critical and finally, that adapted control strategies are crucial for high solar fractions and primary energy efficiencies.

Different control approaches have been carried out for optimisation of SAC-systems. Normally the focus is either on hot water temperature from the solar collector t_{Ko} and t_{Di} entering the desorber or on cooling water temperature t_{Ai} entering the ab- or adsorber of a thermally driven chiller (TDC). E.g. Lecuona et al. (2009) obtain an algorithm for the optimum instantaneous driving temperature $t_{Di,opt}$ that yields a maximum combined efficiency of solar collector and thermally driven chiller. The algorithm is based on the interrelation of increasing chiller efficiency but decreasing collector efficiency with increasing $t_{Ko} \approx t_{Di}$. However, when the temperatures of chilled and cooling water are constant the resulting cooling capacity $\dot{Q}_E$ varies also with $t_{Di,opt}$. The possible mismatch between desired cooling capacity under the instantaneous load condition $\dot{Q}_{E,\ desired}$ and available evaporator capacity $\dot{Q}_E$ at $t_{Di,opt}$ seems not to be considered explicitly, but can be compensated by storages. Eicker et al. (2012) investigated different control strategies for heat rejection devices, including dry and wet cooling towers with and without fan speed control as well as geothermal heat