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Performance analysis of an air conditioning system driven by natural gas

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Abstract

The performance data related to direct-fired double-effect water–lithium bromide absorption chillers in air conditioning systems are scarce. The knowledge of these data is important to validate the models that predict their performance, as well as to establish the design criteria and control strategies that lead to an optimal performance of these machines in air conditioning systems. The objectives of this work were to acquire and analyse the performance data of a 105 kW direct-fired double-effect water–lithium bromide absorption chiller, to simulate with TRNSYS the performance of an air conditioning system in which this machine operates, and to compare the recorded data with the results obtained from simulation. The use of a steady-state model to model the absorption machine predicted an energy consumption 30% lower than that registered at the air conditioning system. This difference was due to the effect of the transient performance of the absorption chiller, not considered by the employed model.

Keywords: Absorption; Direct-fired; Double-effect; Water–lithium bromide; Transient performance; TRNSYS simulation

1. Introduction

The accumulated experience and performance data related to absorption chiller transients are restricted mainly to hot water-driven single-effect water–lithium bromide absorption machines.

Froemming et al. [1] built a test facility at the Arizona State University to evaluate the steady-state and transient performance of absorption chillers used in solar applications. They studied the effect of cold start-up and on–off cycling of the absorption chiller on its COP, finding a reduction of about 50% of the steady-state value at 5.5 cycles/h.

Blinn [2] developed a model that assumed that all the dynamics of the chiller were concentrated in the generator, since the largest transient temperature swings occur in this component, and since the thermal capacitance of the water–lithium bromide solution is much greater than pure water thermal capacitance. For a 10.5 kW commercial absorption chiller, his model predicted a decrease of 5–8% in seasonal COP caused by transients. The comparison between the results provided by the Blinn's absorption chiller model and the experimental results obtained by Froemming et al. showed that the model developed by Blinn underestimated the effects of cold start-up and on–off cycling. This model is included in the standard library of the TRNSYS program [3].

The data related to the dynamic behaviour of direct-fired (natural gas) double-effect water–lithium bromide absorption chillers are scarcer than those recorded from hot water-driven single-effect water–lithium bromide absorption chillers.

Koeppel [4] analysed the field-monitored data of a 1400 kW direct-fired double-effect water–lithium bromide absorption chiller. He associated the cyclic operation observed in the analysed data to the dynamics of the chilled water loop, since the temperature of the outlet chilled water controlled the gas input directly. In Koeppel's opinion, one of the control parameters, the gain, could be incorrectly set, too high, and so slight variations in the chilled water temperature would make the gas valve vary between the maximum and the minimum positions.

Koeppel developed a steady-state model in the environment of the TRNSYS program to investigate its performance. This allowed Koeppel to simulate the performance of the system in which the absorption chiller was running, and to study optimal control strategies. A drop percentage ranging from 10 to 20 in COP, caused by the cycling of the

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Nomenclature

C_p	specific heat (kJ (kg K)$^{-1}$)
COP	coefficient of performance
m	mass flow rate (kg s^{-1})
Q	heat transfer rate (kW)
T	temperature (K)

Subscripts

chw	chilled water
cons	consumption
gen	generator
i	inlet
ng	natural gas
o	outlet
w	water

absorption chiller, was estimated by comparing the field-monitored data to the simulation results.

It is generally acceptable to combine a complex dynamic model of a building with static or quasi-static models of HVAC equipment. However, dynamic HVAC models may be required to study optimal control strategies when equipment transients have a major effect on the system performance.

The objectives of this work were three-fold. The first one was to install a data acquisition system to register the performance of a direct-fired (natural gas) double-effect water–lithium bromide absorption chiller. The second one was to simulate with TRNSYS the performance of the air conditioning system in which the absorption chiller operates, and the third one was to compare the recorded data of cooling demand and energy consumption with the results obtained from simulation.

2. Method

The air conditioning system of the Alberto Colao hall of residence (Technical University of Cartagena) was selected as reference case for this study (Fig. 1).

2.1. Data acquisition system

The data acquisition system installed to register the absorption chiller performance is composed of two easily

Fig. 1. Tested machine at the Alberto Colao hall of residence.

distinguishable parts (Fig. 2). The first part, sited at the Alberto Colao hall of residence, consists mainly of the probes, a data logger and a GSM modem. The functions of this part of the system are to acquire, temporarily store and transmit the chiller operating data.

The second part of the acquisition system, sited on the Muralla del Mar campus, 3 km far from the Alberto Colao hall of residence, consists of a personal computer and a GSM modem. The personal computer manages the communication between the modems and the storage of the recorded data in files.

Fig. 3 shows the situation of the probes in the system. The temperature sensors are labelled with ''T'' and those for mass flow rate measurements with ''M''. In addition to the probes indicated in Fig. 3, the system also has sensors to measure the natural gas flow rate consumption and the meteorological conditions (dry-bulb temperature and relative humidity). The temperature indicated by the sensor at the cooling tower outlet is used to calculate the bypassed cooling water flow rate by means of an energy balance. The data were acquired every minute in order to facilitate the analysis of the chiller transients.

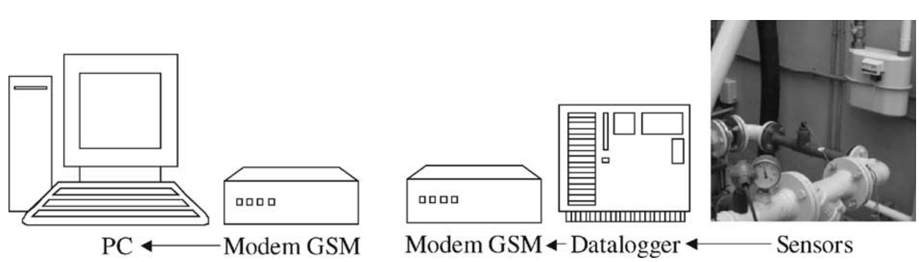

Fig. 2. Data acquisition system scheme.