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Artificial Neural Network modelling of sorption chillers

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Abstract

Solar cooling is still a young and small but growing market with a large potential. An increasing market development of solar cooling and so-called SolarCombiPlus systems (solar thermal systems providing domestic hot water, space heating and space cooling) can help to reduce primary energy demand and hence emissions of greenhouse gases. To support the market entry and to enhance the market penetration it is important to strengthen consumers' confidence in these systems. An important aspect for achieving this goal is a standardised method to predict the performance of the complete solar cooling system under real operating conditions. Nonetheless, objective performance test methods are not yet common standard. In this context a performance test method for solar cooling and SolarCombiPlus systems based on the CTSS method (Component Testing – System Simulation) has been developed by the Research and Testing Centre for Thermal Solar Systems (TZS) of the Institute for Thermodynamics and Thermal Engineering (ITW) at the University of Stuttgart within the project "SolTrans". For the proposed extended CTSS method numerical models are required in order to describe the thermal behaviour of sorption chillers. The main target of the work presented in this paper is dedicated to the development of appropriate models for sorption chillers which can be used for the extended CTSS method. The approach used is the experimental system identification[1] based on Artificial Neural Networks (ANN). In this approach experimentally measured data are used to derive an ANN model which is able to predict the outlet temperatures of a sorption chiller. In the work presented, measured data of an adsorption chiller were used to develop such an ANN model which is suitable to predict the outlet temperatures of the three hydraulic loops of adsorption chillers. The model was validated with measured data obtained under real operating conditions. The simulated output temperatures show a very good agreement with the measured temperatures.

Keywords: CTSS method; EN 12977; Solar thermal cooling; Sorption chiller; Artificial Neural Network; Performance testing

1. Introduction

One possibility to counteract the worldwide increasing electrical energy demand for cooling and the resulting overload of electricity grids in summer months is the use of thermal energy and especially solar thermal energy for cooling. Within solar cooling systems a thermally driven chiller (heat transformer) provides cold water or cold air respectively. So called SolarCombiPlus systems are capable of providing domestic hot water, space heating and space cooling.

Up to now there are no standardised performance test methods for solar thermal cooling or SolarCombiPlus systems available. This may be a barrier for new products to enter the market as no standardised testing and certification is possible. To remove this market barriers and to

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[1] In the field of the experimental system identification a mathematical model of a dynamical system (e.g. sorption chiller) is derived from measurements.

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Nomenclature

Symbol	Quantity
b_k	bias (–)
COP	Coefficient of Performance (–)
i	index of the time step (–)
IA	Index of Agreement (–)
MAE	Mean Absolute Error (K)
N	number of time steps (–)
$Q_{measured}$	transferred energy (measured) (J)
$Q_{predicted}$	transferred energy (predicted) (J)
$RMSE$	Root Mean Square Error (K)
$\dot{V}_{HT}$	volume flow rate of the driving heat circuit of the sorption chiller (HT: high temperature level) (l/s)
$\dot{V}_{LT}$	volume flow rate of the chilled water circuit of the sorption chiller (LT: low temperature level) (l/s)
$\dot{V}_{MT}$	volume flow rate of the heat rejection circuit of the sorption chiller (MT: medium temperature level) (l/s)
w_{ki}	synaptic weights (–)
x_i	input of the ANN (–)
$x_{i,measured}$	measured value (–)
$x_{i,predicted}$	predicted value (–)
$\bar{x}_{i,measured}$	mean of the measured values (–)
y_k	output of the ANN (–)
ε_Q	relative difference in transferred energy (predicted and measured) (%)
$\vartheta_{HT,in}$	fluid inlet temperature of the driving heat circuit of the sorption chiller (HT: high temperature level) (°C)
$\vartheta_{HT,out}$	fluid outlet temperature of the driving heat circuit of the sorption chiller (HT: high temperature level) (°C)
$\vartheta_{LT,in}$	fluid inlet temperature of the chilled water circuit of the sorption chiller (LT: low temperature level) (°C)
$\vartheta_{LT,out}$	fluid outlet temperature of the chilled water circuit of the sorption chiller (LT: low temperature level) (°C)
$\vartheta_{MT,in}$	fluid inlet temperature of the heat rejection circuit of the sorption chiller (MT: medium temperature level) (°C)
$\vartheta_{MT,out}$	fluid outlet temperature of the heat rejection circuit of the sorption chiller (MT: medium temperature level) (°C)

enhance the market penetration of solar cooling systems and SolarCombiPlus systems, the availability of standardised test methods for such systems is necessary. Due to the broad application area and the great variety of system designs of solar cooling and SolarCombiPlus systems, a component based test approach is considered as most promising. A set of component-oriented test standards, the European standard series EN 12977 (DIN, 2012), for testing of solar domestic hot water and solar combisystems already exists. In the EN 12977 series the CTSS method (Component Testing – System Simulation) is defined. Hence an extension of the CTSS method was found to be the most promising way (Frey et al., 2010). The research project “SolTrans” (Solar thermal heat transformers – performance testing and overall assessment) has been initiated by ITW in order to develop performance test methods for solar cooling and SolarCombiPlus systems. Key activities within this project are the development of a performance test method for sorption chillers using the new sorption chiller test facility established at ITW, the extension of the CTSS method towards solar cooling and SolarCombiPlus systems (Frey et al., 2010, 2011), the development of numerical models for specific components (Frey et al., 2011), life cycle analyses for the determination of ecological aspects (Ehrismann et al., 2011) and field tests, i.e. monitoring of solar cooling and SolarCombiPlus systems under real operating conditions.

The present paper describes briefly the performance testing according to the CTSS method and the proposed extension of the CTSS method towards solar cooling and SolarCombiPlus systems. The main focus of the present paper is the development of numerical models for sorption chillers using experimental system identification based on Artificial Neural Networks. After a short overview on applications of ANN in the field of modelling sorption chillers and some basics about ANN the paper describes in detail the newly developed approach of modelling sorption chillers by means of ANN and the results achieved.

2. Performance testing according to the CTSS method

One established procedure to determine the performance of solar domestic hot water systems and solar combisystems (SCS) is the CTSS method, which is already standardised in the EN 12977 series. Fig. 1 shows the schematic process of performance testing according to the CTSS method. In general the procedure can be separated in two steps. The testing of the key components to determine the component parameters and the simulation of the complete system including the implementation and calculation of the system performance in a detailed dynamic component based system simulation program like TRNSYS (TRNSYS, 2010).