Journal of Energy Storage 13 (2017) 40–47

Contents lists available at ScienceDirect

Journal of Energy Storage

journal homepage: www.elsevier.com/locate/est

Simulation of a seasonal, solar-driven sorption storage heating system

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ARTICLE INFO

Article history:
Received 14 February 2017
Received in revised form 1 June 2017
Accepted 3 June 2017
Available online 28 June 2017

Keywords:
Compact thermal energy storage
Closed adsorption
Charge boost
Simulation
Modeling

ABSTRACT

A detailed simulation setup for a closed solid sorption storage system is developed and validated using extensive experimental data of a demonstration test rig built up in the EU-funded project COMTES. The modular implementation of the sorption process allows to discuss enhanced operation modes like the 'charge boost' in the simulation. The validated model is used to optimize the storage system and to predict its performance for several reference scenarios. As an example, a storage system with 6 m^3 of storage material achieves fractional thermal energy savings in the range of 70–75% for a standard single family house in middle Europe.

1. Introduction

The time shift between the abundant supply of solar energy during summer and the heating demand in winter calls for the development of seasonal energy store with high energy density and low thermal losses. Energy storages based on thermochemical material, such as zeolite, have the potential to fulfill both these requirements. Within the EU-funded R&D project COMTES a seasonal solar-driven closed solid sorption storage system was developed for domestic heating and hot water supply [1]. The project benefits from the experience acquired in the preceding projects MODESTORE [2], CWS [3], MonoSorp [4] and HYDES [5]. During summer, the closed sorption storage is charged with solar heat, desorbing the water vapor from the zeolite. The vapor is condensed and stored in a water tank separated from the sorption store. This separation of the chemical partners allows for a loss-free storage of energy for an arbitrarily long period. When needed, in winter, water is evaporated at low pressures using a low-temperature heat source. The vapor is adsorbed at the zeolite, where heat is released. The goal of the project was to prove an energy density significantly higher than the one of a hot water store, to demonstrate the storage system at a realistic scale in the laboratory, and to optimize the storage system using validated simulations. A 1:3 scaled demonstration system with a total zeolite mass of 1500 kg has been monitored in operation in the heating season 2015/2016. First results have been presented in Refs. [1,6–8], and articles dedicated to experimental results are in progress. The present article reports the developed numerical TRNSYS model of the solar sorption heating system and the simulation results considering an optimization of the storage system and its performance for different reference scenarios.

2. Description of the storage system concept

A schematic of the storage system is shown in Fig. 1, details are found in the caption. In summer, evacuated tube collectors provide heat at high temperature (up to about 180 °C) to charge the sorption stores. The water vapor is desorbed and after condensation stored in a water reservoir. In winter, a low temperature heat source is required to evaporate the water again. The vapor is then adsorbed in the sorption store, and the released adsorption enthalpy is used for heating purposes. A cheap and therefore attractive candidate for the low temperature heat source is given by the solar collectors themselves, in combination with the buffer store. Whenever its temperature falls below the set temperature of the heating demand, the solar gains may be used to provide the evaporization enthalpy. The efficiency of this approach is discussed in Section 6. As shown in Fig. 1, several sorption stores are included in the system. This allows for the possibility of a vapor transfer between two of them, called 'charge boost'. With this

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http://dx.doi.org/10.1016/j.est.2017.06.001

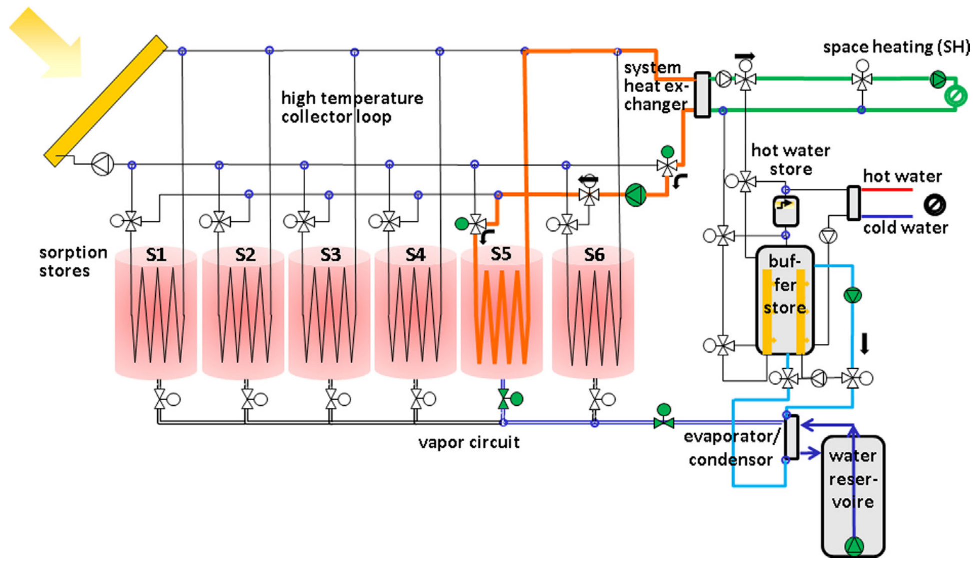

Fig. 1. Schematic of the storage system. The sorption stores are charged during summer with heat provided by the evacuated tube collectors. The water vapor is desorbed and after condensation stored in a water reservoir. In winter, a low temperature heat source is used to evaporate the water. The vapor is then adsorbed in the sorption storage, and the released adsorption enthalpy is used for heating purposes. As an example, the operation mode of discharging store S5 for space heating demands is indicated with colorful highlighted circuits.

methodology, higher states of charge can be reached for a given charging temperature level [8,9]. The present study discusses also the possibility of several subsequent steps of the charge boost, see Section 5.

3. Numerical models

In order to predict the annual performance and to optimize the system as well as the control strategy, a detailed TRNSYS simulation model has been built up, representing the solar sorption system as depicted in Fig. 1. Besides standard components used for modelling the vacuum tube collectors, heat-exchanger, hydraulic devices and water stores, some sorption specific components have been developed within the COMTES project, which are presented in more detail in the following sections.

3.1. Basic concept of modelling the sorption system

In Fig. 2 the TRNSYS components used for modelling the sorption process and the complete vapor circuit of the sorption system are shown. The core components are the sorption store Type 851 and the evaporator/condenser heat exchanger Type 852, which have been developed within the COMTES project to operate together. An equation block, representing vapor connections and valves, allows to select two active components to be connected: either one sorption store with the evaporator/condenser unit (standard ad-/desorption configuration) or two sorption store

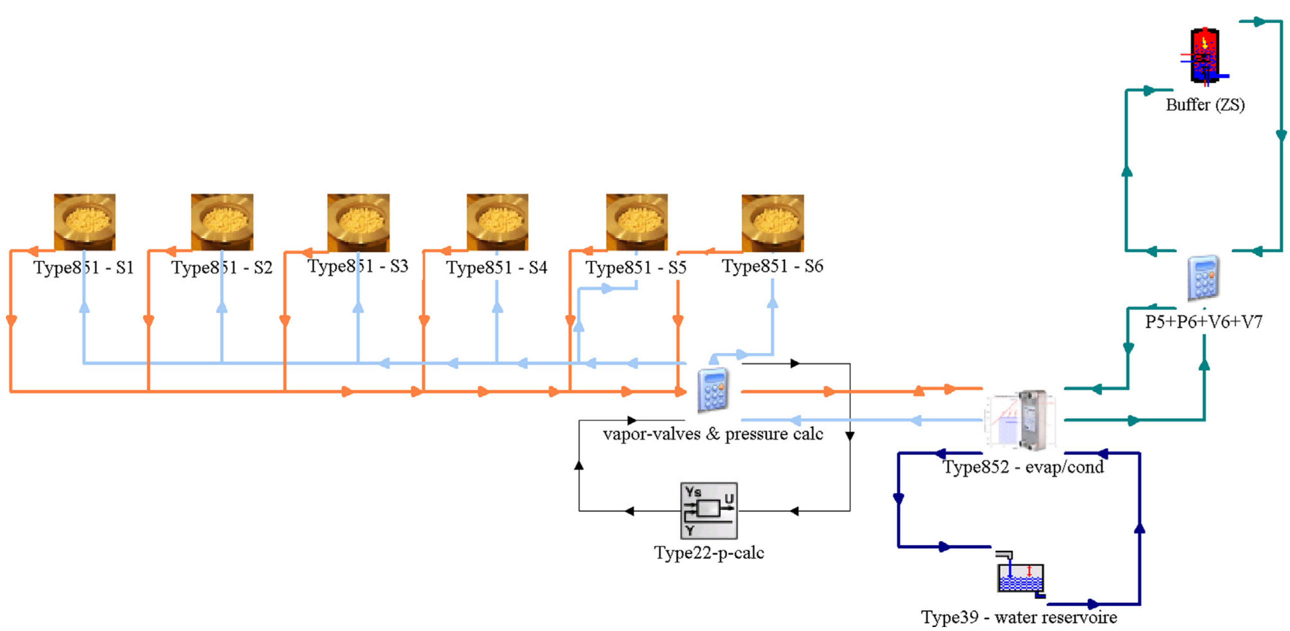

Fig. 2. Overview of TRNSYS Types and hydraulics developed for modelling the sorption process: Sorption stores (Type 851), vapor circuit (red and light blue lines), evaporator/condenser unit (Type 852), water reservoir (Type 39) and buffer store as heat source/sink (Type 340).