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Comparison of the thermal performance of a solar heating system with open and closed solid sorption storage

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Abstract

The aim of this paper is to compare two solar heating systems with different solid sorption storage concepts; an open storage concept with material transport and external reactor and a closed sorption storage concept with the material reservoir as reactor. Both storage concepts are part of system concepts that have been investigated during national projects for a period of more than 3 years each. A TRNSYS model has been developed for each concept and the corresponding mathematical model is described. An emphasis is given on the model simplifications and thus its up- and downscaling possibilities. TRNSYS simulation studies were performed using similar boundary conditions. Hence the simulation results can be compared directly, thus the advantages and disadvantages of both concepts under investigation can be elaborated and assessed.
TRNSYS simulations have been performed for each system concept using the properties of two different thermochemical storage materials (TCM). It is shown that the type of TCM has a significant influence on the systems fractional thermal energy savings. Using silica gel as TCM, both system concepts' performances are only slightly better compared to a standard water-filled storage tank of the same size. The TCM zeolite 13 XBF, a binder free 13 X zeolite, leads to significantly better fractional thermal energy savings. Although the two systems under investigation behave differently, the fractional thermal energy savings are similar. High solar thermal fractions up to a complete solar coverage can be achieved for both storage concepts with moderate collector array and store sizes.

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1. Introduction

In literature zeolites have been described for decades as possible thermochemical storage materials (TCM) [1-5]. Up to now only a few different possible storage concepts for thermochemical energy stores (TCES) have been investigated in a demonstration plant [3, 6-12] although system concept configurations are widely published and discussed [13]. Due to different assumptions and boundary conditions (collector type, heat source/sink, open/closed storage concept) available results of TRNSYS simulations have not been comparable. In addition the TRNSYS models used to predict the TCES behavior are on different states of development and validation is often missing and/or mostly unpublished.

Thus it is the aim of this paper to show and discuss two possible TCES concepts, the corresponding TRNSYS models, to define appropriate boundary conditions and to compare and assess the two TCES concepts directly using the fractional thermal energy savings ($f_{sav,therm}$).

2. Description of the storage concepts' working principles

The working principles of the closed storage concept and the open storage concept are described in this section. The closed storage concept has previously been investigated in the EU and Austrian projects HYDES [6] and MODESTORE [7]. The open storage concept has been developed and investigated in the German project CWS [5, 8, 10-12].

2.1. Closed storage concept ('MODESTORE')

A closed sorption heat store is in fact a kind of thermo-chemical heat pump which is operated under vacuum conditions. This allows water evaporation at a low temperature level and water vapor transport without the need of a pump or fan but just as a result of pressure differences. The hydraulic layout of the analyzed closed-cycle storage system consists of the following key components:

- solar thermal collectors (e.g. evacuated tube collector),
- sorption heat store with integrated heat exchangers for charging and discharging,
- evaporator / condenser connected to a horizontal ground source heat exchanger or boreholes as low temperature heat source and heat sink,
- separate storage tank to store liquid water that has been desorbed and condensed,
- small domestic hot water store to be able to withdraw a sufficient thermal power during domestic hot water preparation.

The solar thermal collectors can charge either the sorption heat store or the domestic hot water store or both in parallel. To fully charge the sorption store temperatures up to 200 °C are required. Therefore, at least highly efficient evacuated tube collectors are necessary. In case that there is not enough heat in the domestic hot water (DHW) store to cover the DHW load, the DHW store can be charged from the sorption store if there is enough sensible heat available. During winter operation, the space heating load is covered directly from the sorption heat store – either by using the sensible heat available in the store or by evaporating water from the separate storage tank using the heat supplied by the ground source heat exchanger and adsorbing the water vapor by the storage material until the desired flow temperature for space heating is reached. The upper part of the DHW store can be recharged once a day from the sorption store. A detailed description of the working principles can be found in [7].