Title

A new TRNSYS Type for solid-gas adsorption thermal energy storage reactors: implementation, validation, and parametric performance assessment of a simplified adsorption-based space-heating system

Abstract

Adsorption-based thermal energy storage (ATES) offers a promising solution to mitigate the temporal mismatch between solar energy availability and residential heating demand. However, its adoption in built environments remains limited mainly due to the lack of comprehensive evaluations of long-term operation and transient behaviour at the system level, particularly when integrated with solar and building subsystems. This study presents the development, validation, and system-level integration of a novel TRNSYS component, Type 2802, designed to simulate the transient thermal behaviour of solid-gas ATES reactors using water vapour as the adsorbate. A detailed mathematical model is implemented in FORTRAN and embedded within TRNSYS. The model is experimentally validated using both data from the literature for small- and large-scale zeolite 13X reactors and in-house discharging tests with zeolite 5A and activated carbon. The model demonstrates strong predictive accuracy across diverse conditions. The resulting TRNSYS Type 2802 is general in the sense that it can easily be used to investigate different adsorbent materials, cylindrical reactor geometries, insulation effectiveness, and inlet conditions.

Beyond validation, Type 2802, configured with zeolite 13X, is tested in an integrated simulation scenario using a simplified ATES system designed to meet residential space heating demand. Parametric investigations are carried out to examine the influence of charging, tank loop flow rates, and the addition of a heat recovery unit on the zeolite energy storage density (ESD) and system coefficient of performance (COP). Results reveal four high-performance operating scenarios, with the highest ESD (122.83 kWh/m^3) and COP (0.164) achieved under the lowest flow rate conditions in the baseline model (without an HRU). Incorporating an HRU with 0.8 effectiveness improves the ESD by up to 40% and increases the COP from 0.164 to 0.337.

Bio

Ali Shahrouzian is a Ph.D. candidate in the Department of Mechanical and Aerospace Engineering at Carleton University, supervised by Prof. Ron Miller and Prof. Jean Duquette. He received both his B.Sc. and M.Sc. degrees in Mechanical Engineering from Iran University of Science and Technology.

His research focuses on the design and development of a novel solar-driven adsorption thermal energy storage system capable of supplying heating requirements for residential buildings located in remote Canadian communities. His work aims to advance sustainable and resilient energy solutions by integrating renewable energy technologies with building thermal systems.