Experimental and Numerical Investigation of a 4 MWh High Temperature Molten Salt Thermocline Storage System with Filler

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Molten salt thermocline storage is a novel concept for storing large amounts of thermal energy at high temperatures of up to 560°C. Instead of storing molten salt in two separate tanks, as in the state-of-art systems, the density difference of hot and cold molten salt is used to maintain stratification inside a single-tank [1]. Advantages are cost savings due to the absence of the second tank, smaller ground coverage, no limitations in tank height due to short shafted pumps, also avoiding unused space at the bottom of the tanks and simplification of the gas handling. However, the greatest cost reduction potential arises from the application of a low cost filler material, substituting a large fraction of the costly molten salt. The total costs for the storage system can therefore be reduced significantly, Pacheco et al. [2] reported a cost reduction potential of 34% that can be increased to more than 50% if the entire storage volume could be utilized. For large scale applications, one challenge is to understand the scalability of this concept. Impacting factors are thermal strain in the tank walls and thermal ratcheting especially for large tank diameters and high temperature differences [2]. The dynamic temperature distribution in the storage is key to assess these issues. Therefore this study aims to investigate the thermocline filler concept both experimentally and numerically.

Several experimental results in pilot scale have been reported so far. The largest one had 170 MWh thermal power and used thermal oil with temperatures up to 300 °C [3]. Later, another plant was operated by Sandia at 400 °C temperature with molten salt, having 2.3 MWh thermal power [4]. Additionally, lab scale experiments with temperatures up to 400 °C have been presented at CEA by Bruch et al. and Rodat et al. [5,6] and at PROMES CNRS by Fasquelle et al. [7] with thermal oil and at Fraunhofer by Seubert et al. [8] with molten salt.

At DLR, a new experimental facility has been set up, extending the upper temperature one step higher to 560°C. With a resulting capacity of 4 MWh it is the world's largest demonstration of molten salt thermocline storage in this temperature range. The test facility for thermal energy storage in molten salts (TESIS) has a capacity of 22 m³ and allows a maximum mass flow of 14.4 tons/h. In the present experimental setup, Solar Salt at maximum temperature is used as heat transferring fluid (HTF) for several consecutive charging and discharging cycles. Three baskets are stacked inside the storage tank, holding a total of 22 tons of basalt rock as filler material. With 166 thermocouples, the temperature distribution along the middle axis and additionally at four planes in two radial directions is measured in detail. A one-dimensional dispersion-concentric numerical model is introduced, which is used for validating the experimental setup and allows studying the thermal behaviour of the experimental plant. Since there are voids without filler material caused by the shape of the baskets, the model is capable to consider a varying composition inside the storage tank. The cyclic behaviour of the experiment is compared to the numerical simulation, providing an excellent foundation for further model validations and extending the numerical studies to larger system models allowing conclusions to be drawn about the scalability of thermocline filler concepts.

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