Experimental and Numerical Investigation of a 4 MWh Single Tank Thermocline Storage

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Introduction

For large scale thermal energy storage at temperatures above 300°C, two-tank molten salt systems mark the current state-of-the-art as they are proven technology in parabolic trough and tower solar thermal power plants. Research is focusing on the utilization of molten salts not only as storage medium but also as heat transferring fluid (HTF) in parabolic trough plants [1].

The current two-tank concept offers serveral cost reduction possibilities. Firstly, instead of storing the hot and cold phase in two separate tanks, the salt could be stored inside a single tank to avoid a large gas volume. The separation of both phases can either be achieved by a floating insulated barrier or simply by the different densities of both phases. Secondly, a high share of the total investment costs of a molten salt storage system is caused by the molten salt itself. For the two-tank system in 50 MWel power plants, this can be as high as half of the total TES costs [2]. In the thermocline with filler concept, a large fraction of the molten salt can be substituted by a cost effective solid material, offering a significant potential for further cost reductions [3]. Finally, gaining operational experience of such systems and the ability to derive optimized operation strategies, promise an additional cost reduction potential.

The “test facility for thermal energy storage in molten salts” (TESIS:store) has been set up at DLR in Cologne, Germany. An outside view of the plant can be seen in Fig. 1. The facility operates at temperatures up to 560 °C and a maximum molten salt mass flow of 4 kg/s. The storage volume has a length of 5.4 m with a total tank volume of 22 m³. The plant allows the investigation of the thermocline concept with and without filler and gaining widespread operation experience. Heat tracing along the containment walls and the piping ensures adiabatic conditions.

Results

In this work, first experimental results of the thermocline concept without filler are presented. As HTF a binary mixture of 60 % $NaNO_3$ and 40 % KNO_3 (Solar Salt) at maximum temperature is used in the plant for several consecutive charging and discharging cycles. The storage volume is equipped with 150 thermocouples which measure the temperature distribution along the middle axis and additionally at four planes in two radial directions each. The aim of the experiments is to understand and improve the molten salt distribution at the inlet and outlet regions as well as the development of the thermocline zone. Particular interest lies in achieving a stable thermocline zone where energetically adverse mixing should be minimized.

The resulting temperature axial profiles at different times during a discharge cycle are shown in Fig. 2. As can be seen from the plot, a stable thermocline zone has been established after several preceding charge and discharge cycles. The publication will present further details of the experimental results, such as the impact of operational parameters on the development of the thermocline zone. Finally, the experimental results are compared to a 1D numerical model which has been implemented in Matlab®.

Fig. 1. TESIS:store test facility with thermocline storage tank (inside the tower) and cold and hot reservoir tanks in front

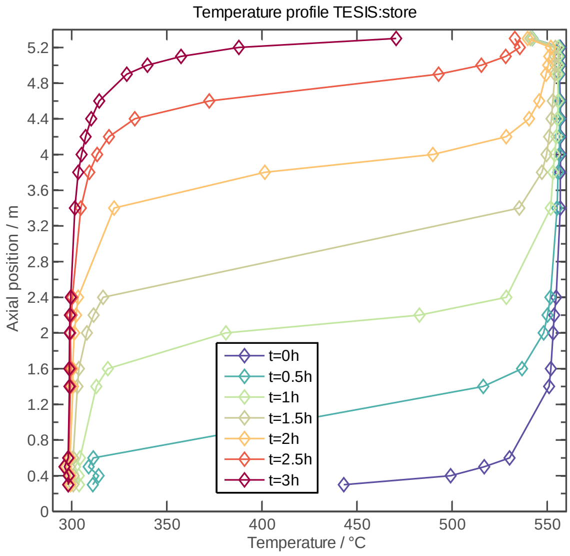

Fig. 2. Measured thermocline temperatures inside the storage volume

References

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