ASIA-PACIFIC
SOLAR RESEARCH CONFERENCE

Evaluation of the Thermal Performance and Cost of Cascade PCMs and Hybrid PCM/Graphite Storage Systems for Concentrated Solar Power Plants

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Abstract

Thermal energy storage, depending on its size, is able to mitigate the short load fluctuations and shift or extend the energy supply of a concentrated solar power (CSP) plant. The current state-of-the-art TES technology in CSP is sensible energy storage with the hot and cold molten salt separately stored in two tanks. Due to the higher storage density and potentially lower cost, phase change material (PCM) has attracted considerable attention to replace the two-tank system for CSP (Steinmann and Tamme, 2008; Fernandes *et al.*, 2012). The aim of this work was to evaluate the thermal performance and cost of various storage configurations for next generation CSP plants.

- Numerical modelling of PCM storage system

A two-dimensional numerical model has been developed to study the thermal performance of a shell-and-tube phase change thermal storage unit as shown in Fig.1. The PCM is filled in the annulus space while the heat transfer fluid (HTF) flows through the inner tubes. This arrangement is the most promising one for a PCM thermal storage unit (TSU) requiring high efficiency with minimum volume (Erek *et al.*, 2005). The transient solid-liquid phase change heat transfer inside the PCM region and the forced convection inside the HTF region in one storage unit (Fig. 1b &1c) was modelled. To validate this numerical model, an experimental test rig was constructed with water as the PCM. The predicted results are in a good agreement with the experimental data.

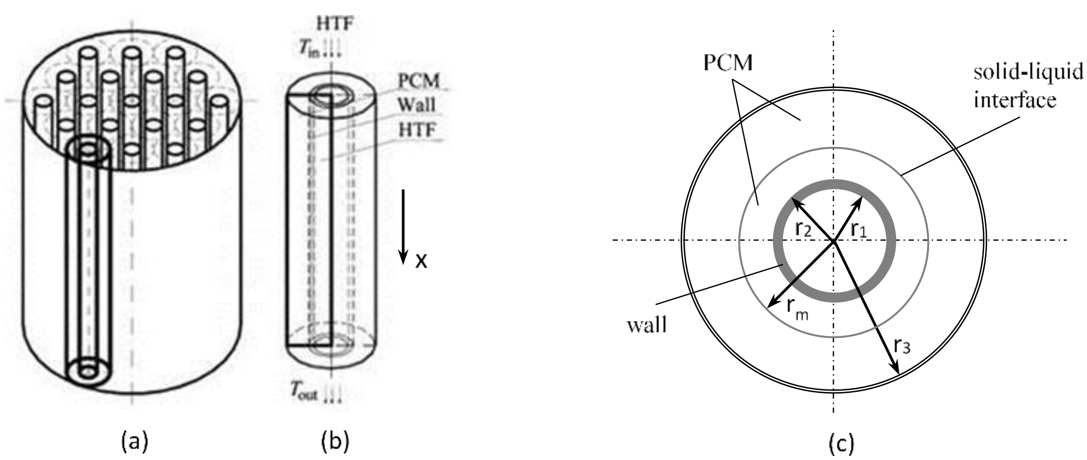

Figure 1. Schematic diagram of (a) a shell-and-tube TSU; (b) one modelled storage unit and (c) top view of the modelled unit.

- Description of CSP configuration

The configuration and representative operating temperatures through this advanced CSP system are shown in Fig.2. It is assumed the power block capacity is 50 MWe with the thermal-to-electricity efficiency of 50 %. The CSP plant is operated under the mode of charging only between 10 am and 4 pm (6 hr) and discharging only between 4 pm and 2 am (10 hr). The total storage capacity is estimated to be 1000 MWthhr, and to achieve this mass flow rate of liquid sodium is estimated to be 800 kg/s and 560 kg/s in charging and discharging, respectively. The plant is idle during the other 8 hr between discharging and charging.

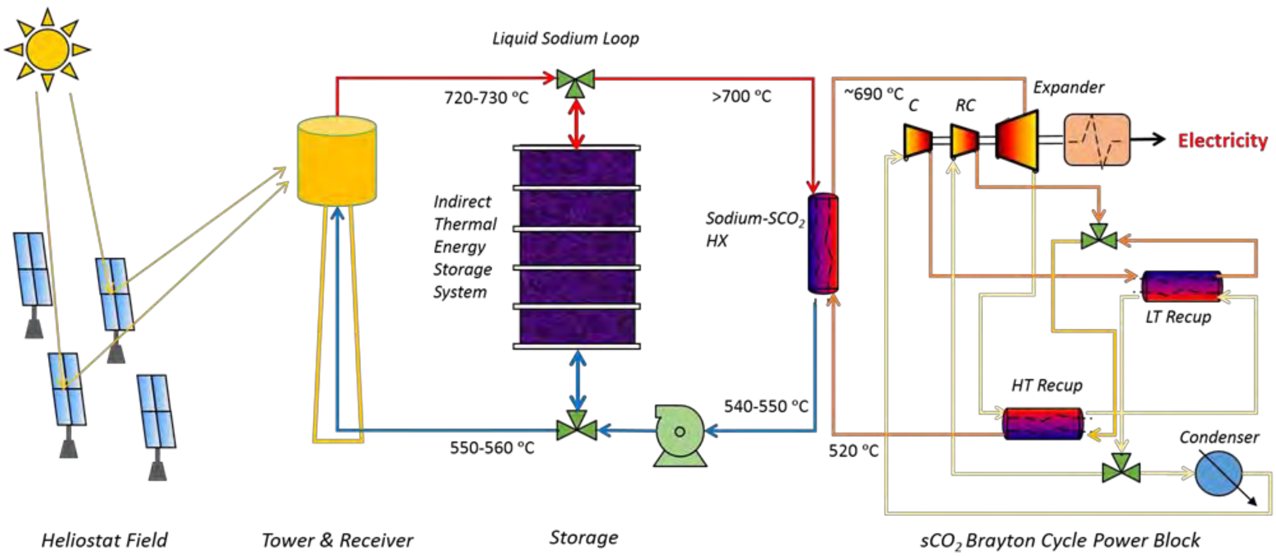

Figure 2. Schematic illustration of an advanced CSP configuration.

- Design and evaluation of TSU

To evaluate the thermal performance and cost of various storage configurations, simulations were undertaken on storage configurations of cascade PCM storage and hybrid PCM/graphite storage systems. Due to the dynamic behaviour of the model in both charging and discharging, the simulation was carried out for 14 consecutive days, during which the charging and discharging process reaches equilibrium conditions. Multiple simulations were conducted with varying amounts of storage media for each storage options and consequently, the required amount of materials was obtained to achieve the discharge thermal energy of 1000 $MW_{th}h$ or slightly below/above. Furthermore, a cost estimation of these systems and the molten chloride two-tank system was undertaken and compared.

References

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