Solar Thermal Energy Storage

M. Jafarian[a], W. Saw[a], S. Lim[b], G. Nathan[a], P. Ashman[a], M. Arjomandi[a]
[a]Centre for Energy Technology, The University of Adelaide, South Australia, Australia
[b]Energy Resource Processing, Oil, Gas and Fuels Programs, CSIRO Energy, Clayton, Australia

Introduction

Thermochemical storage (UA)

- Two types of technologies; namely, an indirectly heated hybrid solar chemical looping combustion (Hy-Sol-CLC) heated by liquid sodium from the ASTRI tubular receiver and a solar-only liquid chemical looping thermal energy storage system (LCL-TES) heated by direct irradiation through ASTRI particle receivers are under investigation.
- Both of these systems achieve exergetic leverage to deliver a higher temperature to the power cycle than that of the solar receiver through releasing the stored energy in such a way as to increase the temperature of the working fluid above that of the receiver.

Sensible particle storage (CSIRO & UA)

- Sensible heat can be stored in high-temperature particles. However, the influence of physical, thermal properties and cost of particles on the annual technical and economic performance of a CSP plant is not well understood.

Aims

Thermochemical storage (UA)

- To develop energy storage systems, enabling storage of solar thermal energy with low cost and minimum exergy destruction.
- To assess these technologies with the view to narrow them down for the next stages of ASTRI.

Sensible particle storage (CSIRO & UA)

- To develop a simplified process model to assess the annual performance of a CSP plant based on the physical and thermal properties of the selected particles.
- To assess the storage cost for a $25MW_e$ plant with a 6 hour particle storage based on commercially available material, equipment and hardware using a natural iron sand as the storage medium.

Methodology

- Combination of Aspen plus and MATLAB will be used to assess the dynamic operation of the processes, using the available thermo-chemical and thermo-physical data in the literature.
- Experimental assessment of the kinetics of the reactions will be employed in the proposed LCL-TES system.
- The design and material construction of the storage tanks are adopted from El-Leathy et al., 2014. The costing of construction material for the tanks was based on the market price and other components was obtained from Beath and Aghaeimeybodi, 2015.

Themo-chemical storage (UA)

Hybrid Solar Chemical looping combustion (Hy-Sol-CLC)

Concentrated solar thermal radiation from a solar collector field is captured and stored by the oxygen carrier particles within the solar fuel reactor. The stored heat in the oxygen carrier particles is then released in the air reactor at a higher temperature to produce a steady power output.

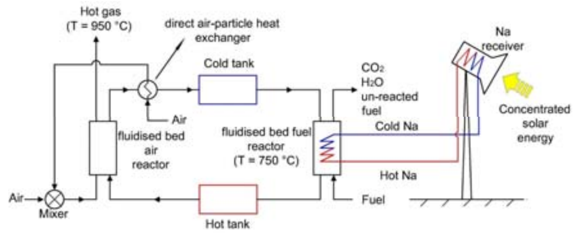

Figure 1. Schematic representation of the indirectly heated Hy-Sol-CLC configuration with an indirect fluidised bed reactor. The high temperature molten sodium produced in the ASTRI solar cavity receiver is used to produce hot particles within the fuel reactor, which are stored in Hot Tank. The cold particles produced in the Air Reactor are stored in the Cold Tank to be fed into the indirectly heated fuel reactor. A direct Air-Particle Heat Exchanger is employed to further cool the particles to the OC particle storage temperature in cold tank.

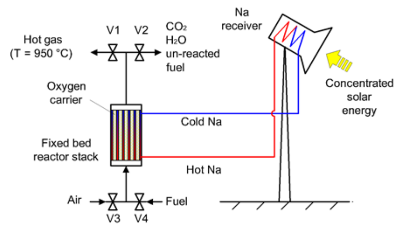

Figure 2. Schematic representation of a periodically operated packed bed Hy-Sol-CLC. The valves 1-4 are proposed to periodically switch the fuel and air streams into the fixed be oxygen carrier. The molten salt receiver is employed to provide the heat for the fuel reactor. A configuration of shell and tube is proposed for the fuel reactor to heat the fixed bed of oxygen carriers using molten sodium.

➢ *Liquid Chemical Looping Solar Thermal Energy Storage (LCL-TES)*

A novel ***commercial in confidence*** technology is under development in ASTRI to address the inherent limitations associated with the application of solid phase storage media for thermo-chemical storage, which in addition to technical challenges limits their temperature to ~1000 °C. This concept has been proved experimentally through TGA/DSC tests.

Sensible particle storage (CSIRO & UA)

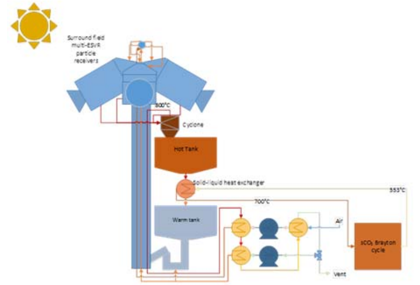

Figure 3. A two tank high temperature particle storage system integrated with a surround field multi-SEVR particle receivers and a moving bed cross-flow solid-liquid (sCO_2) heat exchanger.

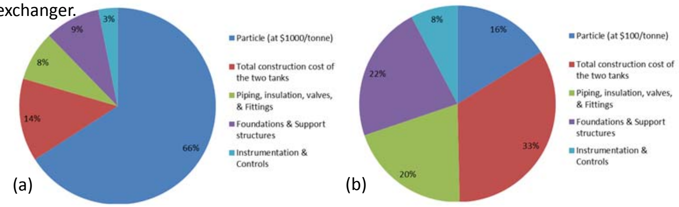

Figure 4. Percentage of breakdown cost in the relative storage cost of the various components for 6 hour particle storage system: a) $44/kWh$_t$ with particle cost at $1000/tonne and b) 16/kWh$_t$ with particle cost at $100/tonne.

Summary

Thermochemical storage (UA)

- Both Hy-Sol-CLC systems can achieve a release temperature of ~ 950 °C with a solar share of up ~ 60 % , while the heat is stored at a temperature of ~ 750 °C.
- The concept of LCL-TES has been proved experimentally.
- Using the LCL-TES system a release temperature of up to 1200 °C can be achieved with a relatively similar receiver temperature.

Sensible particle storage (CSIRO & UA)

- Initial cost analysis suggested that the sensible particle storage cost is around $16/kWh$_t$ to $44/kWh$_t$ depending on the cost of particles ranging from $100/tonne to $1000/tonne).

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