Integration of Different Thermal Energy Storage Technologies into CSP Power Plants

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Principle of solarthermal power plants
Thermodynamic cycle (Clausius-Rankine, Joule)
Principle of solarthermal power plants
Replacement of conventional fuels by solar energy

Sun
Principle of solarthermal power plants
High temperatures through concentration of solar radiation

Parabolic Trough

Tower

Dish
CSP Power Plants: Why Use Thermal Energy Storage?

Thermal energy storage → more operational hours → lower costs
Storage concepts

- Latent Heat
- Salts, solid-solid
- Salts, solid-liquid
- Thermo-chemical
- Sorption
- Gas-solid reaction
- Sensible Heat
- Solid
- Liquid
- Solid/liquid
Storage Systems for DSG Plants
Latent Heat Storage

260 °C – 400 °C 107 bar

- Operating temperature typ. ~300°C
- Energy density: 50-150 kWh/m³
- Constant Temperature
CSP Plant with Thermochemical Storage

\[
AB \rightleftharpoons A + B
\]

- Operating temperature depending on pressure
- Energy density: 100-400 kWh/m³
- Long term storage possible

**TCS-Power project:**
Charging of thermochemical storage reactor
Example for Sensible Heat Storage:
Solar Thermal Power Plant with
Volumetric Air Receiver

→ Operation temperatures 1000°C +
→ Energy density: 50-150 kWh/m³
→ Commercially available
Two-Tank Molten Salt Storage System: Solar Thermal Power Plant

• Heat source: Solar irradiation is focussed at the receiver

• Heat sink: Conventional clausius-rankine cycle
Overview of molten salt storage technology

2-Tank (state of the art)

Thermocline with filler (TCF)

Hot temperature profiles
Cold temperature profiles

Storage Temperature

Time [h]

Temperature [°C]
Comparison of 2-Tank and Thermocline System: Exergy

Energy Source:
(Solar field)

\( T_{in} = 290 \, ^\circ C \)

\( T_{out} = 560 \, ^\circ C \)

Scenario:

- 12 hours charging time
- 2.82 GWh thermal energy

Nominal Exergy:

\(~1.59 \, \text{GWh}\)

Regained Exergy:

\(< 1.59 \, \text{GWh}\)

Parametric study:
Adapt length of storage volume for
- 12 hours charge time and
- permitted drop of exit temperature
Result of Parametric study

- 100s of possible storage configurations
- Every configuration fits into the scenario
- Difference: Regained exergy vs. molten salt holdup (storage size)

![Diagram showing Necessary Fluid Mass (Size of Storage), depending on Exergy Regain with Pareto Optimum indicated.](chart13.png)
## Selected Results of the Parametric Study

<table>
<thead>
<tr>
<th>System</th>
<th>Thermocline, $\varepsilon = 40%$</th>
<th>2-Tank</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permitted change in exit</td>
<td>10</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>temperature ($\Delta T_e$)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Exergy regain ($\Xi$)</td>
<td>99.8</td>
<td>99.8</td>
<td>99.7</td>
</tr>
<tr>
<td>Storage volume ($V_{stor}$)</td>
<td>16.7</td>
<td>14.9</td>
<td>14.6</td>
</tr>
<tr>
<td>Fluid mass ($m_f$)</td>
<td>12.2</td>
<td>10.9</td>
<td>10.7</td>
</tr>
<tr>
<td>Solid mass ($m_s$)</td>
<td>30.0</td>
<td>26.8</td>
<td>26.2</td>
</tr>
</tbody>
</table>
Summary

What to consider for the integration of TES into a power plant:

• Which technology?
  → Utilising the specific advantages of each technology

• Which temperature level?
  → Each technology has limitations for the upper and lower limit

• What are the boundary conditions?
  → Constrictions of attached components and their operation affects utilization of storage technology