Decoupling demands – Thermal stores for CHP

Slavisa Micanovic
Parsons Brinckerhoff
What is a water based thermal store?

• Well insulated hot water accumulator tank designed to receive surplus heat generated by heating production units and supplying heat to the system on demand.

• Usually included in the design of decentralised energy scale CHP plants, but can be integrated with other technologies (i.e. heat pumps, biomass boilers, gas boilers) to prevent cycling during low demand.
What are the benefits of thermal storage in CHP systems?

- Smoothes plant operation by decoupling operation of heating production units (i.e. gas engine) from heat demand
- Economic, extends electricity generation during high tariff hours
- Environmental, reduces CO₂ emissions by increasing on-site electricity generation and reduction of boiler use
- Improves plant operational flexibility (i.e. buffer to gas or biomass boilers at small heat demands)
- Provides short term system resilience
- Can pressurise the system

Disadvantages?
- CAPEX
- Space requirement
- Visual impact for larger units
System integration

- Charging during low heat demands
  - gas boilers are switched off
  - CHP heat output greater than heat demand
- Fully charged
  - return temperature to engine will rise and control engine output before finally switching off
- Discharging during high heat demands
  - CHP heat output less than heat demand
- Fully discharged
  - high level heat in store drops below useable level
  - system calls for supplemental heat from boilers
What do they look like?
Sizing

- Things to consider during design:
  - Space constraints, orientation, height to diameter ratio, more than one unit connected in serial or parallel, pressurised on unpressurised tank, design temperature difference
- First pass sizing

<table>
<thead>
<tr>
<th>CHP thermal output</th>
<th>3,195 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charging time</td>
<td>5 h</td>
</tr>
<tr>
<td>Percentage of CHP output charging TS</td>
<td>70%</td>
</tr>
<tr>
<td>CHP heat stored in TS</td>
<td>11,183 kWh or 40,257 MJ</td>
</tr>
<tr>
<td>Thermal store design dT</td>
<td>25 C</td>
</tr>
<tr>
<td>Required TS active volume</td>
<td>385 m³</td>
</tr>
<tr>
<td>Active as % of design volume</td>
<td>90%</td>
</tr>
<tr>
<td>TS design volume</td>
<td>427 m³</td>
</tr>
<tr>
<td>Height to diameter ratio</td>
<td>2.0</td>
</tr>
<tr>
<td>Estimated diameter</td>
<td>6.5 m</td>
</tr>
<tr>
<td>Estimated height</td>
<td>13.0 m</td>
</tr>
</tbody>
</table>

Heat demand, kW

Charging time 5 h
Percentage of CHP output charging TS 70%
CHP heat stored in TS 11,183 kWh or 40,257 MJ
Thermal store design dT 25 C
Required TS active volume 385 m³
Active as % of design volume 90%
TS design volume 427 m³
Height to diameter ratio 2.0
Estimated diameter 6.5 m
Estimated height 13.0 m
Be realistic about the size!

• The actual size can be constrained by
  • Space availability
  • Planning permission
  • Site access to site (maximum diameter and height possible to deliver via road are 4.5m and 16m)
  • Weight constraints
Energy modelling and fine tuning of thermal store size
Daily Operation

12 April

Heat load, kW

Boiler Natural Gas
TS discharge
TS charge
Not Used
Heat load
TS charge level
Energy modelling and economic results

### Energy Balance

<table>
<thead>
<tr>
<th></th>
<th>No TS</th>
<th>TS 200m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP electricity generation, MWh</td>
<td>14,130</td>
<td>17,372</td>
</tr>
<tr>
<td>CHP heat generation, MWh</td>
<td>13,423</td>
<td>16,503</td>
</tr>
<tr>
<td>CHP gas consumption, MWh</td>
<td>35,312</td>
<td>43,415</td>
</tr>
<tr>
<td>*Boilers gas consumption, MWh</td>
<td>3,422</td>
<td>-</td>
</tr>
<tr>
<td>CO₂ emissions, tonnes</td>
<td>2,956</td>
<td>1,832</td>
</tr>
</tbody>
</table>

Note: *if heat supplied by CHP were to be supplied by gas boilers instead; based on 90% boiler efficiency

### Economic analysis

<table>
<thead>
<tr>
<th></th>
<th>No TS</th>
<th>TS 200m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offset of electricity import from the grid, k£</td>
<td>259.4</td>
<td>based on 8p/kWh</td>
</tr>
<tr>
<td>CHP gas cost, k£</td>
<td>-162.1</td>
<td>based on 2p/kWh</td>
</tr>
<tr>
<td>Offset boiler gas cost, k£</td>
<td>68.4</td>
<td>based on 2p/kWh</td>
</tr>
<tr>
<td>CRC, k£</td>
<td>13.5</td>
<td>based on 12£/tonne</td>
</tr>
<tr>
<td><strong>Total balance, £k</strong></td>
<td><strong>179.3</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Simple payback time

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal store CAPEX, k£</td>
<td>400</td>
</tr>
<tr>
<td>Annual revenues, k£</td>
<td>179.3</td>
</tr>
<tr>
<td>Simple payback time, years</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Not only a vessel!

- Instrumentation
  - Temperature pressure/level sensors, level switches
  - Nitrogen or steam blanket system (unpressurised tanks)
  - Pressure relief/vacuum valves
- Fittings
  - Drain
  - Pipe connections and diffusers
  - Roof and shell manway
  - Access ladder, walkways, etc
Real world photos
Thank you!

Questions?