Optimisation of a solar combisystem including a thermochemical storage

Focus on TRNSYS Tips and Tricks

Samuel Hennaut - BEMS
University of Liège – Arlon Campus Environnement
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Heat your building with solar heat in winter?

Brussels climate - 68 kWh/m² - 100 m²

Space heating demand - Solar radiation

Heating demand [kWh]  Incident solar radiation - 12 m² [kWh]
Content

• Context

• TRNSYS simulation
  • Automatic parameters adaptation
  • Reactor model
  • Pipe model
  • Tank model
  • Parametric analysis

• Conclusion
Heat storage

Sensible

Heat storage

Thermo-chemical

Latent
Thermochemical storage of solar heat

Summer: excess of solar heat

Winter: space heating needs

Source: ECN (2009)
Thermochemical storage: pros and cons

Advantages
- Big energy density
- No thermal losses
- Adaptable temperatures

Disadvantages
- Complex technology
- Subject to ambient conditions
Storage density

Source: Hauer (2010)
Sotherco research project

Solar direct heat + Solar excess Heat + Storage: solid-gas sorption = 100% Heat demand

SiO$_2$-CaCl$_2$ (s) + H$_2$O (g)
System sizing and control

- Tank volume, connections heights and flow rate
- Backups control
- Collector area, slope and technology
- System architecture
- Heating emitter type and control
- TC storage sizing, temperature level and control

Brussels 12.7 kWh/(m².y) 140 m²
3030 kWh/y
System optimization

Parametric analysis for system sizing
- Tank volume
- Collector area
- Cold source temperature (water vaporization)
- Air flow rate in the reactor

Focus on
- Solid mass for chemical storage
- Backup energy needs: DHW + space heating (from TCS)
Automatic modification of parameters

What?
- Define relations between parameters
- Ex: $\dot{m}_{solar} = \dot{m}_{specif} \cdot A_{coll}$

Why?
- Modify automatically linked parameters
- Avoid bias during parametric runs

How?
- Using TRNSYS Equation Editors
- Parameters defined as « String »
Example: Solar loop flow rate
Automatic modification of parameters

Objectives:

1. Modification of flow rate with collector area
2. Modification of flow rate in primary and secondary loop
Automatic modification of parameters

- Tank height; Tank loss coefficient = f(Tank Volume)
- Solar loop flow rate = f(collector area)
- Pipe diameter; Pipe heat loss coefficient = f(solar loop flow rate)

Source: Tank height; tank loss coefficient
IEA-SHC Task 32, Report A2, Heimrath et al., 2007
Thermochemical reactor model

• TRNSYS Type 155: calling MATLAB

• Objective: Use « powerful » MATLAB solvers

```matlab
% solving main system
out_main = fsolve(@system_of_equations_main,y Ini Main,optimset('TolFun',1e-6));
```

• Integration similar to other TRNSYS models
  • Linked to « external » *.m file
Type 155 – Interaction Matlab ↔ TRNSYS

- *.m file code architecture similar to classical type:
  - Respect specific TRNSYS calls

```matlab
if ((trnInfo(7) == 0) && (trnTime - trnStartTime < 1e-6))

% First call of the simulation: initial time step (no iterations)
```

- Import model inputs in Matlab
- Export model outputs to TRNSYS
- Increase calculation time
Level of detail in TRNSYS HVAC simulation

• Is it necessary to simulate pipes or not?
• Influence of tank thermal losses accuracy?

Objective: Give an order of magnitude!
Pipe simulation or not?

**Pipe losses [kWh]**

- 4cm insulation: 500.0 kWh
- 1cm insulation: 800.0 kWh
- no losses: 200.0 kWh
- no pipes: 0.0 kWh

**Part of collector gains lost in pipes [%]**

- 4cm insulation: 5.00%
- 1cm insulation: 8.00%
- no losses: 2.00%
- no pipes: 0.00%

Influence on collector sizing.
Pipe simulation or not?

Total backup energy [kWh]

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Energy [kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>4cm</td>
<td>1810.0</td>
</tr>
<tr>
<td>1cm</td>
<td>1830.0</td>
</tr>
<tr>
<td>No losses</td>
<td>1820.0</td>
</tr>
<tr>
<td>No pipes</td>
<td>1820.0</td>
</tr>
</tbody>
</table>

Solid mass [t]

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Solid mass [t]</th>
</tr>
</thead>
<tbody>
<tr>
<td>4cm</td>
<td>16.3</td>
</tr>
<tr>
<td>1cm</td>
<td>16.5</td>
</tr>
<tr>
<td>No losses</td>
<td>16.4</td>
</tr>
<tr>
<td>No pipes</td>
<td>16.4</td>
</tr>
</tbody>
</table>

+2.3% for 4cm insulation
+3.7% for 1cm insulation
+1.9% for no losses
+3.2% for no pipes
Tank insulation correction factor

\[ UA_{tank,corr} = F_{corr} \cdot (UA_{tank,insulation}) \]

\[ F_{corr} = MAX(1.2; -0.1815 \cdot \ln(V_{tank}) + 1.6875) \]

Source: IEA – SHC Task 32
Tank insulation

Tank losses [kWh]

With correction

Without correction

Part of entering energy lost through tank walls [%]

With correction

Without correction

Influence on collector sizing

52%
Tank insulation

**Total backup energy [kWh]**

- With correction: 16.0 kWh
- Without correction: 16.4 kWh

Difference: +5.6%

**Solid mass [t]**

- With correction: 16.4 t
- Without correction: 15.7 t

Difference: +2.6%
## Parametric study definition

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold source temperature</td>
<td>2; 5; 8 °C</td>
</tr>
<tr>
<td>Collector area</td>
<td>15; 20; 25 m²</td>
</tr>
<tr>
<td>Air flow rate in the reactor</td>
<td>0.25; 0.5; 0.75 kg/s</td>
</tr>
<tr>
<td>Tank volume</td>
<td>0.5; 1 ;2 m³</td>
</tr>
</tbody>
</table>
Analysed variables

Comfort penalty [°h]

Mass of solid necessary for autonomous space heating system[t]
First results

• Minimal solar collector area = $f(T_{\text{cold source}})$
  • 2°C: At least 25 m²
  • 5°C: a bit less than 20 m²
  • 8°C: around 17.5 m²

• Minimal air flow rate in the reactor = $f(T_{\text{cold source}})$
  • 2°C: around 0.75 kg/s
  • 5°C: around 0.5 kg/s
  • 8°C: around 0.25 kg/s

• $V_{\text{tank}} = 2m^3 \rightarrow$ always minimum mass of solid
First results

- Minimum of solid mass
  - Tank volume = 2m³
  - Air flow rate: 0.5 kg/s if $T_{cs} = 8$ or 5 °C; 0.75 kg/s if $T_{cs} = 2$°C
Conclusion

• Level of detail: depends on simulation objective and precision needed
  ➢ Define the objective before starting the simulation
  ➢ Decision depends of the « quality » of system components: quality of insulation, size of the tank, temperature difference

• Thermochemical storage is a quite promising solution to increase heat storage energy density and for seasonal storage, especially with a « hot » cold source