Flexibility in Smart Grids by Heat Pumps and Thermal Energy Storage

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What is flexibility?

Definition from Eurelectric:

“[...], **flexibility** is the *modification* of generation injection and/or *consumption patterns* in reaction to an external signal (price signal or activation) in order to provide a *service* within the energy system.”
Flexibility – how to measure it?

Definition from Eurelectric:

“ [...] , flexibility is the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system.”

**Signal price:**
Energy Costs

**Signal demand peak:**
Average block length

**Signal load profile:**
Concentration of running periods

Energy costs at German EPEX SPOT day ahead Market
Where is the limit?

Exploration of possibilities with basic model of heating system.

Assumptions: Renovated old single family house with an annual energy demand of 100 kWh/m² in Zürich in the year 2013, Energy prices: EPEX Spot Day Ahead market prices from Germany.
Modelling the residential heating system

Model implemented with Carnot toolbox in Matlab/Simulink

- Solar radiation
- Ambient temperature

System boundary

Building

Floor heating or radiator heating

- Domestic hot water
- Thermal storage
- Air/Water heat pump

Controller

On/Off

Cost electricity

Ambient temperature (current/forecast)

Solar radiation
Ambient temperature
Modelling approach for components

Example: Process illustrated for heat pump

Complex model (experimentally validated)

Operating characteristic of the heat pump

Yearly simulation of the whole system

All component models are experimentally validated or in-silico verified.
Which concentration can be achieved?

Daily average fraction with heat pump (HP) switched off during heating period (results for year 2013):

Results:
- Improvement of flexibility by more than 50%.
- Heat pump capacity has stronger influence than size of storage system on fraction of day without heat pump activity.

Assumptions: Design temperature -10 °C: heat capacity generated 8 kW, heat capacity required 7.4 kW, inlet/outlet temperatures of heat pump 45 °C/ 55 °C, max. storage temperature 60 °C
Longer off-blocks for more control power

Average length of periods with blocked heat pump in 2013

Results:
- Integration of storage helps to triple average length of blocks
- Larger storage size helps to increase block length

Assumptions: Design temperature -10 °C: heat capacity generated 8 kW, heat capacity required 7.4 kW, inlet/outlet temperatures of heat pump 45 °C/ 55 °C, max. storage temperature 60 °C
Drawback of high flexibility solution

Seasonal performance factor for 2013

Results:
- Larger storage size helps to recover seasonal performance factor (SPF)

Assumptions: Design temperature -10 °C: heat capacity generated 8 kW, heat capacity required 7.4 kW, inlet/outlet temperatures of heat pump 45 °C/ 55 °C, max. storage temperature 60 °C
### How about other buildings?

<table>
<thead>
<tr>
<th>Type</th>
<th>Single family house (SFH 100)</th>
<th>Single family house (SFH 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual energy demand for heating</td>
<td>100 kWh/a/m²</td>
<td>15 kWh/a/m²</td>
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</tbody>
</table>

Source: Office for statistics in the canton of Zurich, Switzerland
Flexibility for different buildings

Comparison of flexibility for 2013 in simulations with SFH15 and SFH100

Assumptions:
- Design temperature -10 °C: heat capacity generated 8 kW, heat capacity required 7.4 kW,
- inlet/outlet temperatures of heat pump 45 °C/ 55 °C, max. storage temperature 60 °C

Results:
- SHF15 offers high flexibility even with conventional control
- Effect of heat pump scaling and storage size less pronounced than for SFH100.
Conclusions

- Thermal storages can
  - improve the flexibility by up to 50%.
  - prolong the periods without heat pump activity.

- High flexibility may cause efficiency losses to be minimised by suitable control algorithms and additional thermal storage capacity.

- Largest benefit from thermal storages for renovated old buildings, which form a majority in the Swiss building park.
Call for help

In the H2020-project Heat4Cool Lucerne university investigates with 12 European Partners novel retrofitting solutions.

A retrofitting planner will be developed as a fast tool to estimate energy demand, energy costs and other performance indicators of the different configurations of the heating system.

Please help us to design it conveniently for the future users, by answering this questionnaire:
Thank you for your attention

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