Hardware-in-the-Loop test bench setup and its application to determine seasonal performance of heat pump systems

Markus Nürenberg
motivation, methodology

Static evaluations
- Predetermined test procedure
- Focus only on component
- No coverage of dynamic effects, responses and system synergies

Dynamic evaluation + wider system boundary
- Evaluate whole HP-systems
- Demand driven test procedure
- Dynamic responses are taken into account

HiL + test day reduction
- HiL test bench
- Building as simulation model
- Demand profiles
- Method to reduce test days
Hardware-in-the-Loop

home energy system

heat pump

system controller

hardware

software
### Project Goals

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of rooms</td>
<td>10</td>
</tr>
<tr>
<td>Net ground area</td>
<td>172 m²</td>
</tr>
<tr>
<td>Window surface</td>
<td>24 m²</td>
</tr>
<tr>
<td>Insulation standard</td>
<td>HIO 84</td>
</tr>
<tr>
<td>Standard heat load</td>
<td>7.7 kW</td>
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**Building as Simulation Model** (suitable for HP and CHP systems)
project goals

building as simulation model (suitable for HP and CHP systems)

demand profiles

- DHW
- EN 16147 profile ‘L’
- ventilation, set temperatures and internal gains
  - stochastic profile coupled with presence profile
- weather TRY
project goals

- clustering approach with optimization to determine cluster centers
- quotient of the sum of the weighted daily consumption and generation, respectively
- key features
  - realistic daily gradients
  - no limitation towards time span or weather data
  - sensitivity analysis necessary

building as simulation model (suitable for HP and CHP systems)

demand profiles

method to reduce test days
project goals

- building as simulation model (suitable for HP and CHP systems)
- demand profiles
- method to reduce test days
- HiL test bench

- climate chamber for outdoor units
- hydraulic test bench
  - sink for space heating
  - sink for DHW
  - source for ground water and brine HP
- coupling of PLC and simulation
- data handling
test bench: climate chamber I

1. fan
2. heat exchanger
   (low temp. chiller)
3. heat exchanger
   (district heating)
4. electrical heater
5. humidifier
6. swirl diffusors
7. temperature and
   humidity sensors

controlled test area
test bench: dynamic of the climate chamber

![Graph showing the dynamic of the climate chamber with relative humidity and temperature over time.](image-url)
test bench: hydraulic (heat sink and heat source)

8 hydraulic circuits
each works as heat sink or source
supplied by district heating and cooling
high precision measuring components
test object: water/water heat pump

home energy system

heat pump

system controller

city inlet
results of water/water hp test series

\[
\text{DPF} = 3.3
\]

Dynamic Performance Factor

<table>
<thead>
<tr>
<th></th>
<th>Qth</th>
<th>Wel</th>
<th>Qth</th>
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<tr>
<td>kWh</td>
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<td>30.08</td>
<td></td>
<td></td>
<td>11.1</td>
<td></td>
<td>27.2</td>
<td></td>
<td>01.06</td>
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</tbody>
</table>

\[0.36, 0.87, 0.97, 1.06, 1.08, 1.07, 1.61, 1.84\] kWh

experiment 1

experiment 2

experiment 3

delta min/max
results and outlook

test method for dynamic evaluation

various HiL interfaces

promising results for Round Robin Test

multi purpose development platform
Thank you for your attention!

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