INTEGRATION OF DECENTRALIZED SOLAR HEAT GENERATION TO A LOW-TEMPERATURE DISTRICT HEATING NETWORK VIA SUBSTATION NET-METERING

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4DH
4th Generation District Heating Technologies and Systems
Overview

• District Heating/Cooling,
  – Key technology to (1) achieve a higher overall energy system efficiency,
  – and (2) integrate non-conventional heat resources,

• Low Temperature District Heating (55/25 °C)
  – Response to challenges: low-energy buildings (losses > consumption, in summer)
  – Enhance heat recovery from low-grade heat sources: Solar DH

• Integration of LT Substation using a mix of low-exergy resources
  – Solar heat, DH return flow, (DH supply/forward flow used when necessary)

• Performance comparison (Energy, Collector efficiency)
  – Different possibilities for connection/feeding load

• Effects on the substation’s load curve (aggregated demand pattern)
  Thermodynamic modelling & simulation
System Description

Low-Temperature Substation + Solar Collector

1. DH Supply
2. DH Return
3. LT Supply
4. LT Return
5. Subs. Return
6. Collector In
7. Collector Out

• Low-Temperature Network (Load)
  – Multi-dwelling building (50 - 75 apartments)
  – LT Supply/Return temp.: 55/25°C
  – Location: Stockholm
  – Maximum Load = 250 kW\textsubscript{th}
  – Heat Demand: 1,01 GWh\textsubscript{th}/yr

• Weather Data
  – Typical meteorological year (hourly)

• Solar Collector (Flat plate type)
  – Collector area: 200m\textsuperscript{2}
  – 150 kW\textsubscript{th} peak (@ 1000 W/m\textsuperscript{2})
  – Output temp. range: 65 – 90°C
  – No storage tank
  – Network short-term storage: 90% eff.

  – Collector output estimation according to European standard EN12975

Introduction | System Description | Methods | Results | Discussion | Concluding Remarks |
Substation-Collector System

- Solar collector coupled to the primary DH network
  - Allow short-term network storage
- Use of two low-exergy resources: (1) Solar thermal (2) DH return flow
  - DH supply flow used to boost temperature level

- Solar collector, connection configurations:

  **LT Substation + R-S collector**
  - 65°C min

  **LT Substation + R-R collector**
  - 65°C
  - No min T

  **LT Substation + sR-R collector**
  - 65°C
  - No min T
Methodology

Modelling Assumptions:

- Aggregated demand patterns (SH + DHW)
- Use of average values over the year (loads, solar radiation, ...)
- Full and partial load (steady-state)
- Pumping energy neglected (~2% of energy delivered)

Operation Targets:

- Use the least DH supply/forward flow
- Aim for low substation return temperatures
- Enhance solar heat generation
- Use most solar heat at the substation (reduced use of short-term storage)
Results - Annual

Collector Performance:

<table>
<thead>
<tr>
<th>Operating Hours</th>
<th>Collector Efficiency</th>
<th>MWh/yr</th>
<th>% of yr Demand</th>
<th>kWh/m² yr of coll. area</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Sol</td>
<td>0</td>
<td>n/a</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R-S</td>
<td>1468</td>
<td>29%</td>
<td>43,4</td>
<td>4,3%</td>
</tr>
<tr>
<td>R-R</td>
<td>2071</td>
<td>27%</td>
<td>52,0</td>
<td>5,2%</td>
</tr>
<tr>
<td>sR-R</td>
<td>2266</td>
<td>30%</td>
<td>60,9</td>
<td>6,1%</td>
</tr>
</tbody>
</table>

- 4340 hr/yr with sunlight
- 8760 hr/yr total

~80% in summertime

Baseline: Without Solar Collector

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Results - Summer

- Solar thermal displaces both DHs and DHr flows
- Using the LT substation return allows for:
  - Further solar heat recovered
  - Higher collector efficiency
  - Less energy stored in the DH network
  - Increased auto-sufficiency
**Discussion**

**Residual LDC**

- Dependent on penetration level of solar heat generation
- Ramping (morning/evening)
- Role of TES (potential)
- Phase-out conventional sources (during summer)

**Metering & Charges**

<table>
<thead>
<tr>
<th>Demand</th>
<th>1002 MWh/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Price</td>
<td>0,09 EUR/kWh</td>
</tr>
<tr>
<td>Solar Heat</td>
<td>0,07 EUR/kWh</td>
</tr>
<tr>
<td>Consumption</td>
<td>90,2 k EUR/yr</td>
</tr>
</tbody>
</table>

- **Individually**
  - Total Consumption & Total Generation
    - Savings (per year)
      - R-S: 3,4% → 3,0 k EUR/yr
      - R-R: 4,0% → 3,6 k EUR/yr
      - sR-R: 4,7% → 4,3 k EUR/yr

- **Alternative Models**
  - Net Consumption & Network Input (DHs pipe)
    - Savings (per year)
      - R-S: 3,4% → 3,0 k EUR/yr
      - R-R: 4,7% → 4,3 k EUR/yr
      - sR-R: 6,1% → 5,5 k EUR/yr
Concluding Remarks

• Combination of low-exergy heat resources
  – Solar heat, DH return flow

• Solar collector connection: S-R / R-R / sR-R
  – sR-R: better performance, more solar heat recovered, less use of network storage

• Applications (advantages) of system integration
  – Small-scale (local) -> large scale
  – Heat recovery from intermittent sources (surplus heat, electricity, TES)

• Potential to supply a larger fraction of solar heat during summer
  – High solar heat capacity + short-term thermal energy storage (TES)

• Techno-economics
  – Pricing, connection fees, storage fees ...
Thank you!

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Supporting Slides

International Conference on Smart Energy Systems and 4th Generation District Heating, Copenhagen, 25-26 August 2015
Input Curves

Temperature [°C]

00:00 00:00 00:00 00:00 00:00 00:00 00:00 00:00

DH supply  DH return  LT supply  LT return

Supporting Slides | Input curves |