Solar-CHP - Development of multifunctional systems combining CHP with solar thermal plants

M.Sc. Magdalena Berberich, Lisa Willwerth, Dipl.-Ing. Laure Deschaintre, Dipl.-Ing. Thomas Schmidt

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Motivation

• Increasing fluctuating electricity from renewable energy sources
• Decreasing electricity prices
• Decreasing operation hours of fossil CHP plants
  • Often increasing heat production in fossil peak load boiler
• Alternative heat supply in district heating systems needed
• Solution: solar thermal and heat storage?
  • Research project „Solar-KWK“ (Solar-CHP)
    • Development of simulation models in Trnsys 17
    • Operation of the CHP plant in an economical feasible way

CHP: Combined Heat and Power
The electricity market in Germany

- European Energy Exchange EPEX
  - Different auctions
  - Physical Electricity Index (Phelix)
  - Hourly data

- Control energy (Germany)
  - Power system stability in four zones
  - Positive and negative control energy
  - Three qualities
  - Data of 15 minutes periods

Primary  Secondary  Tertiary control energy

0  30 s  5 min  15 min  Time

Data analysis - European Power Exchange EPEX

- **Average price 43 €/MWh** for 2012
- **Average price 38 €/MWh** for 2013
- **Average price 33 €/MWh** for 2014
Data-Analysis - market of control energy

Paid service and energy rates

Tertiary control energy: access in 9 % of the 15 min periods
Secondary control energy: access in 99 % of the 15 min periods
Development of a CHP simulation model

- Empirical model based on characteristic curves
  - efficiencies and power
  - time-based behaviour
- Technical boundary conditions
- Data from literature, operators, and manufacturers

![Diagram of CHP system boundary]

- Engine output
- Electrical energy demand
- Generated electrical power
- Generated thermal power
- Power loss
Development of a control model

- Power-led control of the CHP model
- Operation if EPEX price > marginal costs of cogenerated electricity
- Provision of tertiary control energy
- Price data for the years 2012, 2013 and 2014

- Calculation of marginal costs (€/MWh)
  - Variable operation costs
  - Fuel
  - Electricity demand of the CHP plant
  - Reimburse of energy tax
  - Heat credit
  - Legal CHP reimbursement („Kraft-Wärme-Kopplungsgesetz KWKG“)
Development of a control model

- Power-led control of the CHP model
- Operation if EPEX price > marginal costs of cogenerated electricity
- Provision of tertiary control energy
- Price data for the years 2012, 2013 and 2014
System simulation results

Year 2014 | heat-led | power-led | with solar
--- | --- | --- | ---
Pel CHP (MW) | 15 | 15 | 15
Storage (m³) | 440 | 440 | 13600
Collector area (m²) | 0 | 0 | 59300
Solar (%) | 0 | 0 | 15,1
CHP (%) | 59,2 | 15,7 | 14,2
Boiler (%) | 40,8 | 84,3 | 70,9
Revenue (T€) | -193 | 324 | 313

Yearly heat demand 126 GWh
System simulation results

Yearly heat demand 126 GWh

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<thead>
<tr>
<th></th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
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<tbody>
<tr>
<td>power-led</td>
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<tr>
<td>CHP (%)</td>
<td>31.6</td>
<td>21.9</td>
<td>15.7</td>
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<td>Boiler (%)</td>
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<td>78.1</td>
<td>84.3</td>
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<td>Revenue (T€)</td>
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<td>640</td>
<td>324</td>
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</tbody>
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CHP - 2012: 15 (MW)
CHP - 2013: 15 (MW)
CHP - 2014: 15 (MW)
Storage - 2012: 440 (m³)
Storage - 2013: 440 (m³)
Storage - 2014: 440 (m³)
CHP (%) - 2012: 31.6%
CHP (%) - 2013: 21.9%
CHP (%) - 2014: 15.7%
Boiler (%) - 2012: 68.4%
Boiler (%) - 2013: 78.1%
Boiler (%) - 2014: 84.3%
Revenue (T€) - 2012: 905
Revenue (T€) - 2013: 640
Revenue (T€) - 2014: 324

Yearly heat demand 126 GWh
Conclusion

• Simulations confirmed the anticipation
  CHP plants are getting more and more uneconomic with the developing electricity market in Germany

• Solution: solar thermal and heat storage!
  • Heat share from gas boiler reduced
  • Heat production and economical feasibility of CHP preserved

➢ Further optimisation of the developed simulation system
➢ Simulations of existing CHP plants
➢ Sensitivity analysis and risk estimates for investments enabled
Thank you for your attention

www.solar-district-heating.eu

M.Sc. Magdalena Berberich
berberich@solites.de

Steinbeis Research Institute
for Solar and Sustainable
Thermal Energy Systems
www.solites.de