Multi-Objectives, Multi-Period Optimization of district energy systems

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1. Motivation & Objectives

- Develop a systematic procedure for design and operation optimization of district energy systems
- Developed model includes:
  - Energy integration
  - Multi-objectives
  - Process design
  - Daily thermal storage
  - GIS base network design

2. Methodology

The basic concept of the developed model is the decomposition of the problem into several parts (Figure 1). Three major steps are:

- I. Structuring phase for collecting and manipulating data
- II. Multi-objective nonlinear optimization phase for optimizing the design and operation of an energy system.
- III. Post-Processing phase for detail evaluation of the Pareto frontier.

3. Preliminary results

Design a district energy system for a city with 550,000 inhabitants.

I. Data structuring

- a) Demand profile: typical days
- b) A list of available energy source

<table>
<thead>
<tr>
<th>Resources</th>
<th>Δ CO₂: [kg/MJ]</th>
<th>Price: [€/MJ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>0.3071</td>
<td>0.0196</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.0641</td>
<td>0.0092</td>
</tr>
<tr>
<td>Biomass</td>
<td>0</td>
<td>0.0036</td>
</tr>
<tr>
<td>SNG</td>
<td>0</td>
<td>0.0099</td>
</tr>
</tbody>
</table>

C) List of equipments

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Reference: [MWth, kWel]</th>
<th>Ranges: [MWth, kWel]</th>
<th>βel</th>
<th>αel</th>
<th>O&amp;M [€/Mw]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler (NG)</td>
<td>420, 500</td>
<td>[200, 210]</td>
<td>14</td>
<td>84</td>
<td>3.5</td>
</tr>
<tr>
<td>Boiler (BM)</td>
<td>420, 500</td>
<td>[210, 210]</td>
<td>17</td>
<td>84</td>
<td>10.4</td>
</tr>
<tr>
<td>Engine (NG)</td>
<td>500</td>
<td>[100, 100]</td>
<td>25</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Engine (SNG)</td>
<td>500</td>
<td>[50, 50]</td>
<td>25</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Gasifier</td>
<td>200</td>
<td>[200, 200]</td>
<td>67</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Gas turbine</td>
<td>200</td>
<td>[200, 200]</td>
<td>73</td>
<td>14</td>
<td>50</td>
</tr>
<tr>
<td>Steam turbine</td>
<td>300</td>
<td>[200, 200]</td>
<td>32</td>
<td>272</td>
<td>10</td>
</tr>
<tr>
<td>ORC</td>
<td>200</td>
<td>[20, 20]</td>
<td>38.5</td>
<td>96</td>
<td>30</td>
</tr>
</tbody>
</table>

BM: Biomass, NG: Natural gas,

II. Multi-objectives, multi-periods optimization results

Respect to three objectives:
- i. the annual investment cost
- ii. the operating cost
- iii. the overall CO₂ emissions

Decision variables in the multi-objective optimization phase

Optimization steps

- Master Optimization: (EMOO) Type of equipments and their maximum available size.
- Thermo-economic simulation: The corresponding thermodynamic states and the investment turnkey cost of equipment
- Slave optimizer: (EIO) Utilization rate and the operation strategy of selected equipment

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