Early Building Design: Heating and Cooling Plant Approach the Architect

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28.06.2012

2nd Colloquium of the Munich School of Engineering
Buildings Should Consume Less Energy

Buildings account for 40% of total energy consumption (Germany, US, World).

Roughly a half of that is consumed by HVAC.

A significant reduction potential exists in HVAC (Heating, Cooling and Air-Conditioning) domain.

Regulations, Legislations, National policies, Certification

e.g. EnEV 2012 (implements EU-Directive 2010/31/EU and DIN V 18599:2010)

BEP Simulation Tools

- Imagine we omit to simulate or test cars and plains, as we commonly do with buildings! – simulation improves planning
- Buildings as smart grid objects – predicting building behaviour demands simulation

BEP – Building Energy Performance

Sources:
- http://service.enev-online.de/bestellen/EnEV_2012_Was_kommt_Novelle_Energieeinsparverordnung.pdf)
Introducing the Developed Tool

**When** to apply the tool?
- Appliable already during conceptual design

**Which** building component is in focus?
- Primary HVAC – energy generation and storage (Step 3)

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Step 1
Reduce:
- Gains
- Losses
Improve the building envelope

Step 2
Improve Secondary HVAC:
- Do not oversize
- Utilize renewables
- Improve control

Step 3
Improve Primary HVAC:
- Do not oversize
- Utilize renewables
- Improve control

Background illustration taken from: DIN V 18599-1
### Basic Features of the Tool

#### Time domain simulation (hourly quasi-stationary)
- Implementing intermittent RES and thermal storage
- Considering part load efficiency;

#### Preconfigured system models and control
- Optimal boiler and chiller staging
- The user does not configure the system
- Preset values provided and adaptive to provided user input

#### Component size optimization, always combinable with an annual solar ration target:
- Total cost minimization
- Investment cost minimization
- Carbon emission minimization
- Fuel consumption minimization

#### Obligatory input
- Climate data
- Building thermal load ("ideal load") data
Tool Structure – Developer Perspective

Optimizer

Simulator

System Model Performance (Ch. 3)

Costs & Emissions (Ch. 4)

Penalties & Objective (Ch. 5)

Min?

Optimal Result

External Data

Objective

W

B

cond1

cond2

S

capacity

on-off

O

delivered

Adapted from Lehrstuhl für Energiewirtschaft und Anwendungstechnik

Lehrstuhl für Energiewirtschaft und Anwendungstechnik
Prof. Dr.-Ing. U. Wagner, Prof. Dr. rer. nat. Th. Hamacher
PROBA - primary system optimization for buildings targeting architects
Simplicity is the essence of happiness.
Alternative design

Initial building can reach the solar ratio (SR) target of 20%.

If higher SR is required, the design is to be changed and optimization rerun.

Alternative Design:

- Optimal chiller sizes:
  - First chiller: 50 kW
  - Second chiller: 700 kW

- Optimal PV areas:
  - Optimal tilt: 310 m²
  - Horizontal surface: 230 m²
  - Facing north: 0 m²
  - Facing south: 0 m²
  - Facing west: 0 m²
  - Facing east: 0 m²

- Annuity cost of such a configuration:
  - Investment cost: 18220.8 Euro
  - Running cost: 13367.3 Euro
  - Total cost: 31588.1 Euro

- Achieved solar ratio: The target is met if the solar penalty = 0.
  - Solar ratio: 0.303218%
  - Solar Penalty: 0

- Annual carbon emission:
  - CO2 Emission: 167295 kg/year
Results and advantages of PROBA utilization:

- The tool provides dimensions, annual costs, energy consumption and emissions of the optimized system.
- Comparing alternative designs leads to early recognition of environmental or/and financial advantages of particular systems and components compared to other.

Beyond PROBA – the potentials of the underlying simulation tool:

- Abilities to perform energy analysis of the existing building stock or help planning multiple buildings.
- Optimization of primary HVAC systems of existing buildings (retrofit planning)

Outlook

- Model validation and the consequent model adjustments
- Integration of additional generation and storage components
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PROBA Tool
### Optimal chiller sizes

<table>
<thead>
<tr>
<th>Chiller Type</th>
<th>Size (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First chiller</td>
<td>120</td>
</tr>
<tr>
<td>Second chiller</td>
<td>780</td>
</tr>
</tbody>
</table>

### Optimal PV areas

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>420</td>
</tr>
<tr>
<td>Facing north</td>
<td>0</td>
</tr>
<tr>
<td>Facing south</td>
<td>0</td>
</tr>
<tr>
<td>Facing west</td>
<td>0</td>
</tr>
<tr>
<td>Facing east</td>
<td>0</td>
</tr>
</tbody>
</table>

### Annuity cost of such a configuration

<table>
<thead>
<tr>
<th>Cost Type</th>
<th>Cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment cost</td>
<td>17183.7</td>
</tr>
<tr>
<td>Running cost</td>
<td>15902.7</td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
<td>33086.4</td>
</tr>
</tbody>
</table>

### Achieved solar ratio

- **Solar ratio**: 0.207849%
- **Solar Penalty**: 0

### Annual carbon emission

- **CO₂ Emission**: 268225 kg/year
**Optimal chiller sizes**
- First chiller: 80 kW
- Second chiller: 700 kW

**Optimal PV areas**
- Optimal tilt: 310 m²
- Horizontal surface: 230 m²
- Facing north: 0 m²
- Facing south: 0 m²
- Facing west: 0 m²
- Facing east: 0 m²

**Annuity cost of such a configuration**
- Investment cost: 18220.8 Euro
- Running cost: 13307.3 Euro
- Total cost: 31528.1 Euro

**Achieved solar ratio. The target is met if the solar penalty = 0.**
- Solar ratio: 0.303218%
- Solar Penalty: 0

**Annual carbon emission**
- CO2 Emission: 167295 kg/year
**Objective**

- Solar ratio target
- Ideal heating or cooling load profile
- Available area for PV or solar collectors

**Preset Cost Data**
- Prices: gas, oil, biomass, water, electricity
- Rates: interest, price development
- Factors: investment, maintenance, CO2 emissions for fuels

**Preset Technical Data**
- Component performance data: efficiency, COP, Chiller type: centrifugal, reciprocating, Secondary system characteristics: radiator or panel heating

**External Data**
- Optimizer – Performance based design optimization of a predefined primary system

**Results**
- Objective function
- Parameter analysis
- For a chosen SM: Optimized component sizes, Investment and running costs, CO2 emissions