PEAR-Energy Efficient Automation and Control of Buildings

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Inhalt

- Introduction to PEAR
  - Starting situation/ current problems
  - Goals and Method
  - Demonstration building
- Results: air-conditioning offices
  - Configuration of AHUs
  - Weather conditions/ Set points
  - Energy performance of AHUs
  - Comparison of Simulation and Monitoring data
- Conclusions
Introduction: Starting situation/ current problems

- Expected operation behaviour and energy performance of HVAC systems can be achieved in hardly any building from the beginning.

- HVAC systems become more and more complex which have to be handled by the Facility Management in operation.

- Responsibility of efficient performance of HVAC systems is given to Facility Management which is not their duty and core know-how.

- Appropriate control strategies of HVAC systems should be implemented according to the operation conditions and energy efficiency measures set up in the planning phase.

- Lack of information from planning phase to implementation of control strategies by control engineering during construction phase.

- Current commissioning phase and operation test phase focuses on the basic functionality of HVAC system and components not on energy efficient behaviour.

- Facility Management often fights for years to achieve acceptable operation behaviour and energy performance of HVAC systems.
Introduction: Goals and Method

- In PEAR a method for a **pre-check** of control strategies adapted to HVAC systems in buildings was developed and tried out in a demonstration building.

- Three step method:
  1. Development of appropriate control strategies by dynamic simulations in cooperation with control engineering of building project.
  2. Pre-check of developed control strategies with Hardware in the Loop (HIL) method.
  3. Monitoring evaluation and optimising operations.

- **HIL** here means:
  - Hardware: applied controller of control company.
  - Virtual part: HVAC system in the building (simulated).
  - Loop:
    - behaviour of **HVAC system** is **simulated** and gives inputs to controller.
    - **Controller** reacts physically and gives a control output to the HVAC system.
Introduction: Goals and Method

- **Demonstration Building:**
  - Newly finished Head Quarter of the Austrian „Post“ company in the 3rd district of Vienna with 47.300 m² gross area
  - Usage: Mainly offices and a Shopping Centre

- **Three parts of the HVAC system were selected for a PEAR pre-check:**
  - Air-conditioning offices
  - Concrete core activation for cooling
  - Free cooling system (dry heat-rejection/sprinkler basin)

- **PEAR project partner:**
  - AIT – Austrian Institute of Technology (project lead)
  - Österreichische Post AG
  - teamgmi Ingenieurbüro GmbH
  - IBO Österreichisches Institut für Bauen und Ökologie GmbH
  - BPS Engineering Technisches Büro zur Planung Haustechnischer Anlagen GmbH

- **Results shown here:**
  - Air-conditioning offices: simulation of control strategies and monitoring evaluation
# Introduction: Demonstration Building

## Integration Process

|-------------------------|-----------------------------|------------------------|--------------------------|-----------------------------|------------------|

### Construction Phase (from April 2015)

| M1: Integration Control Company from Construction Company in PEAR |
| M2: Integration of PEAR results in HVAC control by Control Company |
| M3: Handover from Control Company to Facility Management |

### Commissioning/Operating Test Phase

| M4: Monitoring data transfer to AIT |
| M5: Move in Shopping Center |
| M6: Move in Post employees |

### Optimising Operations

- Milestones Construction Process
- Milestones for integration of PEAR results in Construction and Operation Process
Results: Air-conditioning offices

- Configuration of Air Handling Units (AHUs)
  - AHU 01: 36,000 m³/h
  - AHU 02: 33,000 m³/h

- Purpose of AHUs:
  - Fresh air supply (35 m³/h*P)
  - Humidity control
  - **NOT**: heating/cooling

Source: demonstration building, 11.04.2018
Results: Air-conditioning offices

- Climate conditions: Monitoring data
  - 14.10.2017 – 15.06.2018 (8 month)

- Set points AHUs: Design values
  - Supply air temperature: 22°C
  - Return air humidity:
    - min. 7 g/kg (40% r.H.)
    - max. 9 g/kg (60% r.H.)
Results: Air-conditioning offices

- Evaluation of achieved Set points: Monitoring data
  - Time period: 19.11.2017 – 15.06.2018
  - Supply air temperature set point can be achieved very well
  - Return air humidity is occasionally below the set point, but still in an acceptable range; AHU 02 had a damaged humidifier in given time period
Results: Air-conditioning offices

- Energy performance of AHUs: Monitoring data
  - Specific fan capacity: lower than design values
  - Electricity demand:
    - AHU 01: 33% higher than design value
    - AHU 02: 37% higher than design value
- Reason: longer run times than foreseen in design phase

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>AHU 01 Design</th>
<th>AHU 01 Monitoring</th>
<th>AHU 02 Design</th>
<th>AHU 02 Monitoring</th>
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<tr>
<td>Volume flow</td>
<td>m³/h</td>
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<td>-</td>
<td>31.000</td>
<td>-</td>
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<td>Specific fan capacity (SFP-4) max.</td>
<td>Wh/m³</td>
<td>1,10</td>
<td>0,82</td>
<td>1,10</td>
<td>0,95</td>
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<tr>
<td>Electrical capacity max.</td>
<td>kW</td>
<td>39,60</td>
<td>29,66</td>
<td>34,40</td>
<td>29,36</td>
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<tr>
<td>Electricity demand</td>
<td>kWh/(7 month)</td>
<td>42.500</td>
<td>56.500</td>
<td>41.200</td>
<td>56.300</td>
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</table>
Results: Air-conditioning offices

- Comparison of Simulation and Monitoring data
  - Operation modes according to design/simulation (left)
  - Operation modes according to Monitoring data (right)
    - Heating coil II is operating in winter, therefore mode 2' and mode 4'
    - Supply air humidifier is in operation when cooling coil is on, therefore Modus -2'

<table>
<thead>
<tr>
<th>mode</th>
<th>enthalpy rotor</th>
<th>heating coil I</th>
<th>cooling coil</th>
<th>humidifier</th>
<th>heating coil II</th>
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<td>OFF</td>
</tr>
<tr>
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<td>ON</td>
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<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>-3</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>-4</td>
<td>ON</td>
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<td>-5</td>
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<th>heating coil II</th>
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<td>ON</td>
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<tr>
<td>2'</td>
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<td>OFF</td>
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<td>ON</td>
</tr>
<tr>
<td>2</td>
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<td>ON</td>
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<td>OFF</td>
<td>OFF</td>
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<tr>
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</table>
Results: Air-conditioning offices

- Comparison of Simulation and Monitoring data
  - Additional modes mode 2’, mode 4’ and mode -2’ only occur on few hours in transition time
  - Mode 2 (without humidifier) operates too often → is reflected in not reaching humidity set point

<table>
<thead>
<tr>
<th></th>
<th>sum</th>
<th>mode-7</th>
<th>mode-6</th>
<th>mode-5</th>
<th>mode-4</th>
<th>mode-3</th>
<th>mode-2</th>
<th>mode-2'</th>
<th>mode-1</th>
<th>mode0</th>
<th>mode 1</th>
<th>mode 2</th>
<th>mode 2'</th>
<th>mode 3</th>
<th>mode 4</th>
<th>mode 4'</th>
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<tbody>
<tr>
<td><strong>AHU 01</strong></td>
<td>2.541</td>
<td>28</td>
<td>0</td>
<td>6</td>
<td>100</td>
<td>14</td>
<td>6</td>
<td>324</td>
<td>8</td>
<td>24</td>
<td>113</td>
<td>784</td>
<td>23</td>
<td>16</td>
<td>956</td>
<td>122</td>
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<tr>
<td><strong>AHU 02</strong></td>
<td>2.612</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>43</td>
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<td>101</td>
<td>98</td>
<td>800</td>
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<td>59</td>
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<td><strong>Simulation V14</strong></td>
<td>3.326</td>
<td>826</td>
<td>268</td>
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<td>72</td>
<td>144</td>
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<td>1.731</td>
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Conclusions I

- Control air-conditioning offices:
  - Supply air temperature set point can be achieved very well
  - Return air humidity is occasionally below the set point, but still in an acceptable range; AHU 02 had a damaged humidifier in given time period
  - Humidifier is operating when cooling coil is “on” in transition time; this should be monitored further in summer time to see if it is an operation failure or not
  - The high maximum set point of 24°C of supply air when the outside air is very cold should be reduced to generally 22°C as the AHUs have no heating purpose → heating coil II is probably not necessary for heating modes as intended
  - Electricity demand of AHU 01 is 33% and AHU 02 37% higher than foreseen in design phase due to longer operation times:
    • Design phase: 07:00 – 19:00
    • Operation: 06:00 – 21:00; sometimes also on the weekends
    • AHUs have no heating or cooling function
    • Purpose of AHUs: fresh air supply and humidity control → only useful when people are present
Conclusions II

- Experience of PEAR method in demonstration building:
  - HIL pre-check of control strategies showed various **programming failures** in advance
  - The **operation behaviour** and **energy performance** of HVAC systems is close to the expected values right from the beginning by using PEAR method
  - **Deviations** or **operation failures** can be more easily identified by comparison of monitoring data with simulation results
  - **Lack of information** from planning phase to implementation of control strategies by control engineering during construction phase is closed → control strategies are set up together
  - **Quality assurance** and **proper commissioning** of HVAC system is still necessary and can not be replaced by PEAR method
  - **Responsibility** of efficient performance of HVAC systems is given back to HVAC planner and control engineering company who have the necessary know-how