Testing of a price-based decentralized system for power balancing on real-life HVAC installation

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Motivation ... for change

• There is consistency of opinions that the power grids and power markets have to change.
Management systems

- Communication dependent control systems
- Production management
- Demand side management / Demand response
- Incentives:
  - Regulations
  - Prices /cost
- Reactive / proactive control
Control system types

• Centralized
  – Model-based
  – Optimization
  – Heuristics

• Distributed
  – Hierarchical
  – Agent-based
  – Market-based
Real-Life test

• How to test control algorithms outside of simulated environment?
  – Infrastructure
  – Communication mediums
  – Reaction time of real device
  – Physical limitations of devices

• Which devices can be used?
KEZO research centre

- Research institute located in Jabłonna near Warsaw, Poland.
- Different laboratories, a number of renewable power sources (wind turbine, photovoltaic modules).
- BMS and measuring equipment.
Waterloop in KEZO

• Heat pumps water-air in closed circuit.
• Both heating and cooling options.
• Temperature of water for heating purposes: 0-30°C, for cooling: 0-40°C.
• In KEZO has 17 heat pumps of different type and maximum power:
  – 1-phase – 1,5 kW
  – 3-phase – 2,5 kW
Operation of the B2_0_17 – north side
Operation of the B2_1_14 – south side
Algorithm

• Algorithm developed and published by Gerwin Hoogsteen from University of Twente.

• Active control methodology, which goal is nearly instantaneously control of a group of devices to maintain certain level of supply and demand of power.

• Method uses double-sided auction (market based approach)

• Might be implemented as hierarchical control structure
Price (cost) calculation

• Step1:
  – Registering devices.
  – Gathering of the demand functions
  – Sum of price
Calculation of equilibrium price

• Step 2:
  – Balancing supply and demand
  – Calculating the clearing price

Supply of 250 kW
Supply of 170 kW
Supply of 90 kW

Gives price: -350
Gives price: 0
Gives price: 500
Modification of demand function

- The demand function is not fixed – it depends on current temperature of the room.

\[ dT = 2 \times \text{hysteresis} \]

\[ X_1 = -1000 + 1999 \left( \frac{T_r - T_s}{dT} \right) \]

\[ X_2 = \begin{cases} 
0, & x \leq a \\
2 \left( \frac{x - a}{b - a} \right)^2, & a \leq x \leq \frac{a + b}{2} \\
1 - s \left( \frac{x - b}{b - a} \right)^2, & \frac{a + b}{2} \leq x \leq b \\
1, & x \geq b 
\end{cases} \]
Modification of demand function
Maximum supply level

- The amount of supplied power is determining the clearing price.
- The limits were imposed based on the general averages for peak hours.
Experiments setup

- Case 1: basic operation of the pumps based only on temperature.
- Case 2: operation with automatic system with cost function 1.
- Case 3: operation with automatic system with cost function 2.
- Case 4: operation with automatic system with limited power.
Operation of heat pumps

Problems:

- Temperatures – difficult to find very similar days.
- Missing values – investigation is still on-going.
2019-06-20 — 2019-06-23 — sum of power
Limiting the peak power

Limit: 10 kW

Limit: 5 kW
Conclusions

• Automatic system should first consider the „healthy” working conditions for heat pumps – frequent switching off and on is not acceptable.
• The limitations for the management is stricter than previously expected.
• Algorithms worked as foreseen, especially for limiting the peak power consumed.