5th International Conference on Smart Energy Systems
Copenhagen, 10-11 September 2019
#SESAAU2019

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

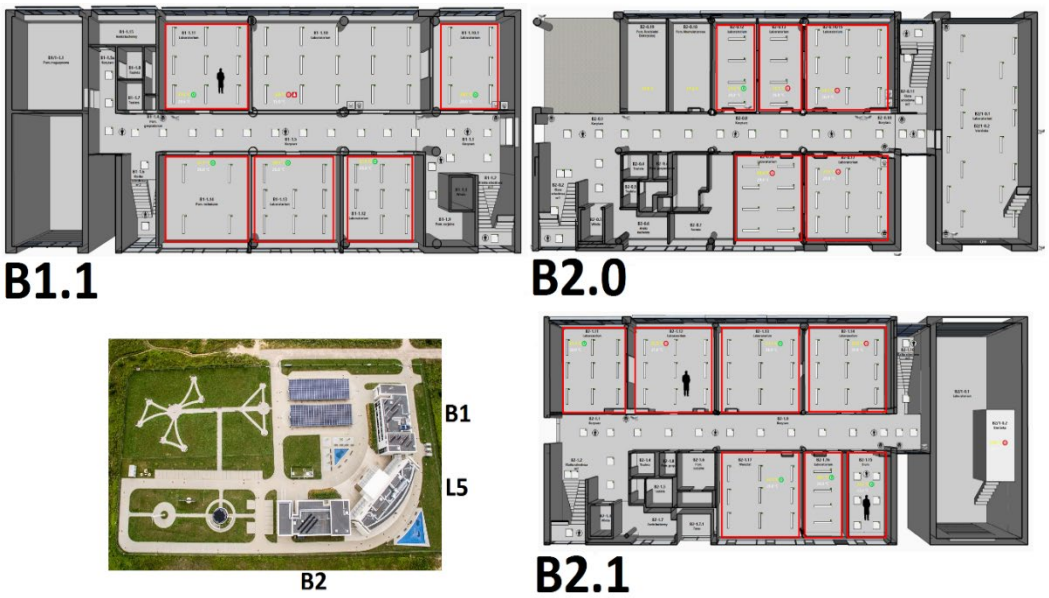
- Centralized
  - Model-based
  - Optimization
  - Heuristics
- Distributed
  - Hierarchical
  - Agent-based
  - Market-based

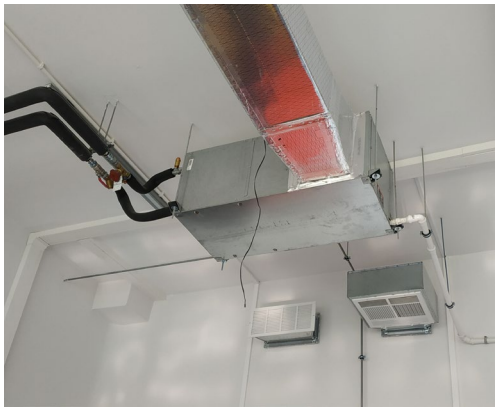
Real-Life test

- 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.

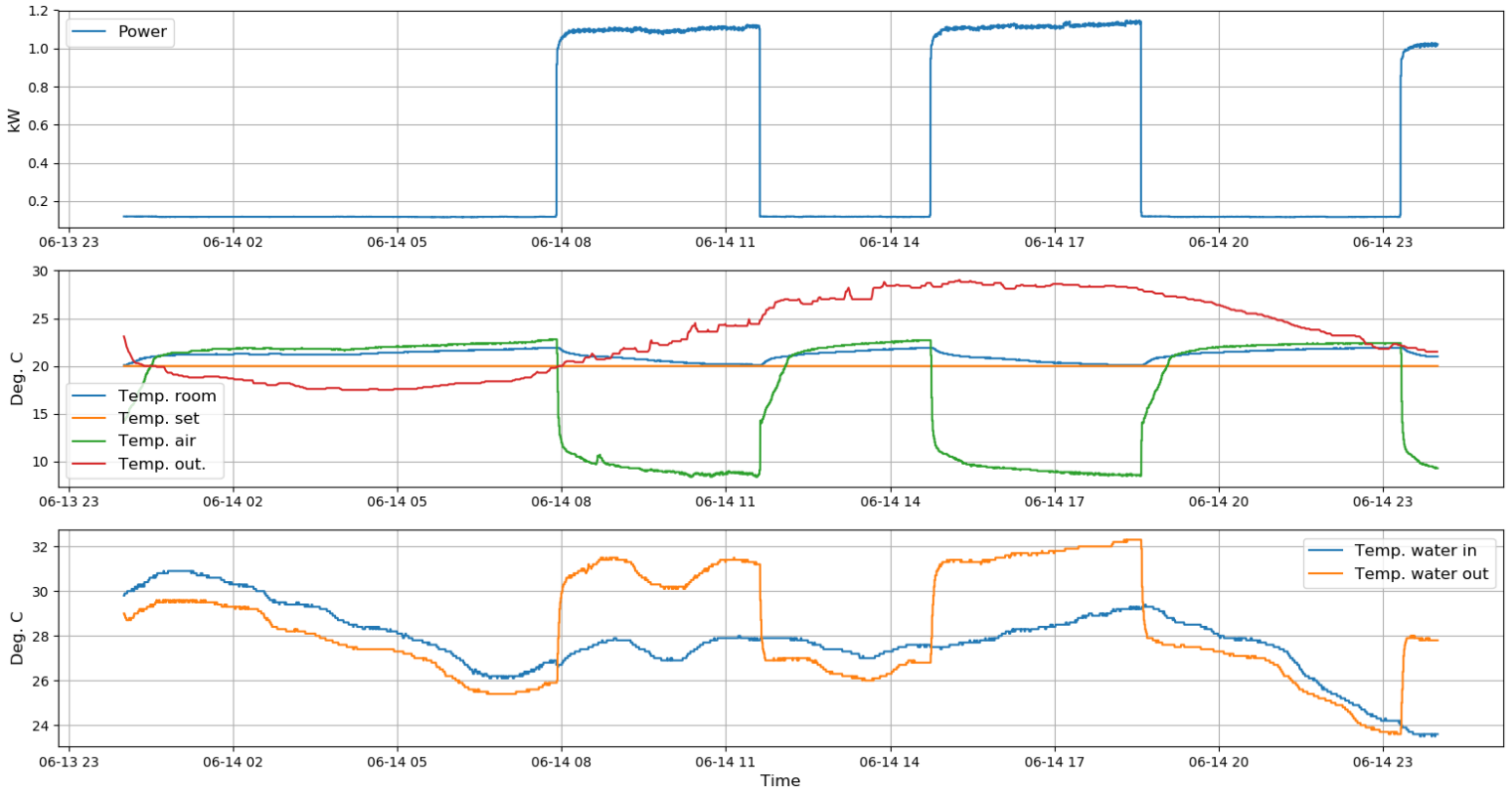




Waterloop in KEZO

- 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



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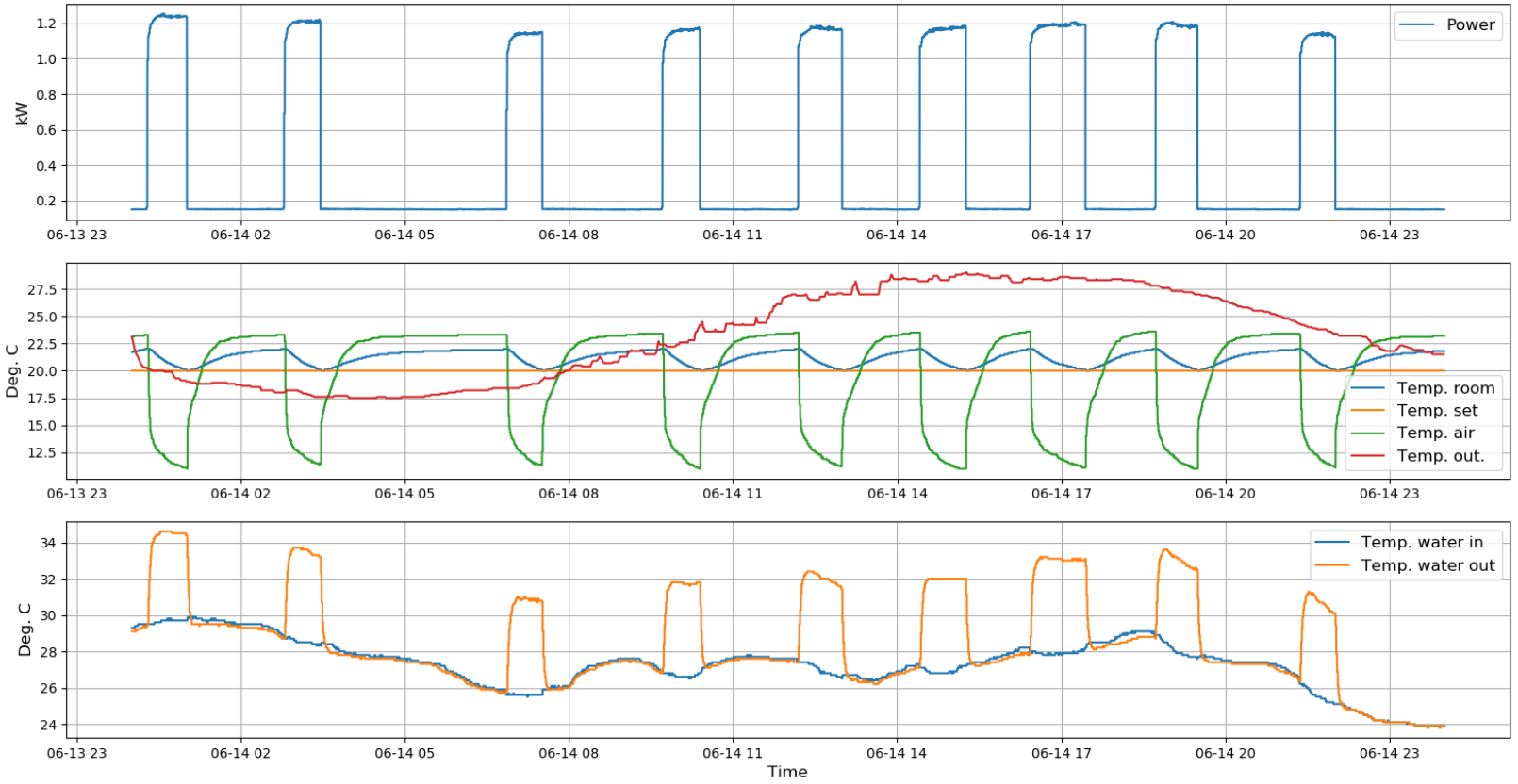
Operation of the B2_1_14 – south side



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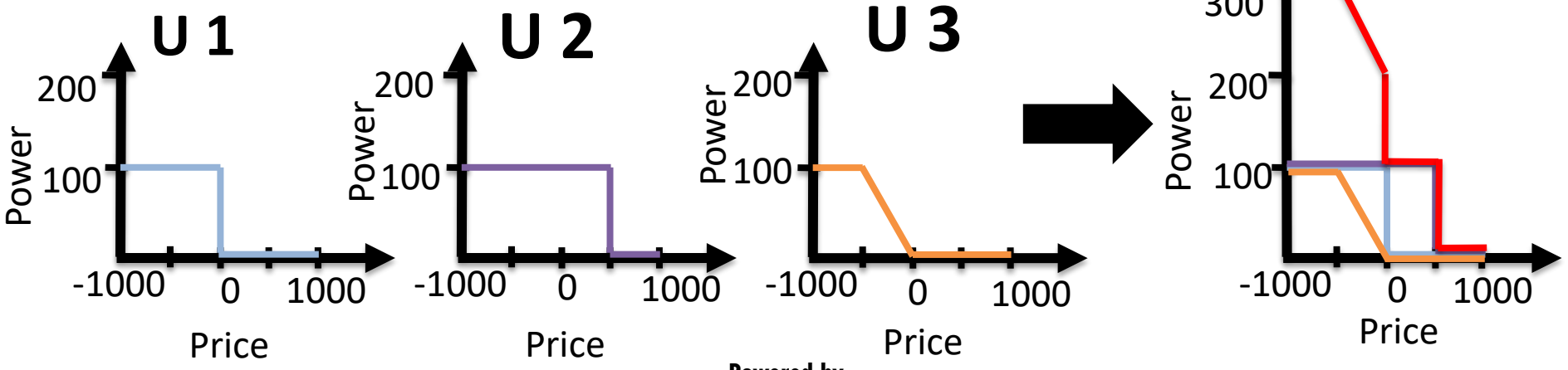
Algorithm

- 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

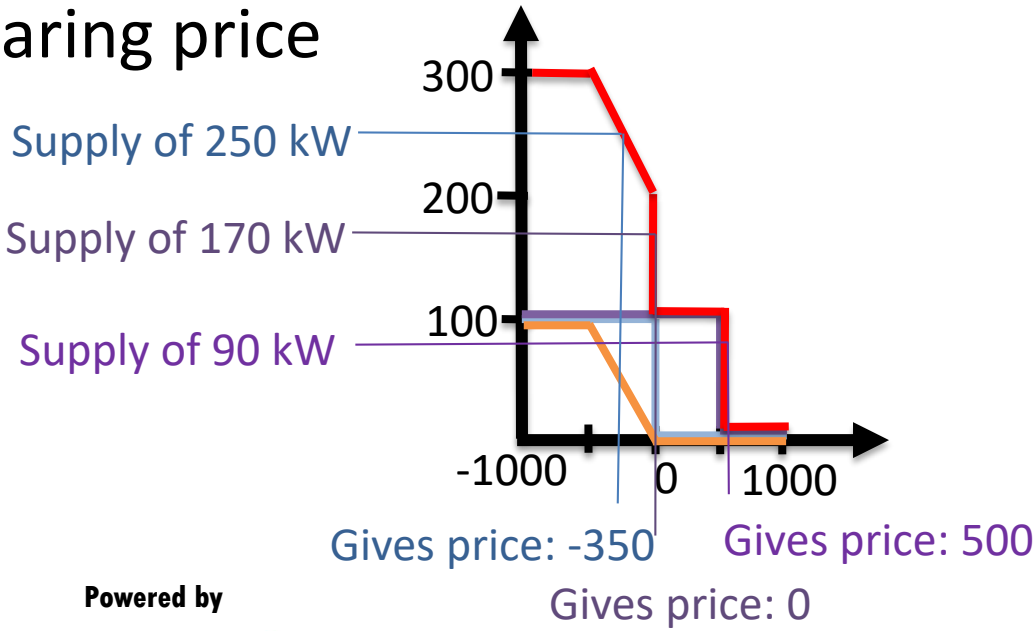
Price (cost) calculation

- 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

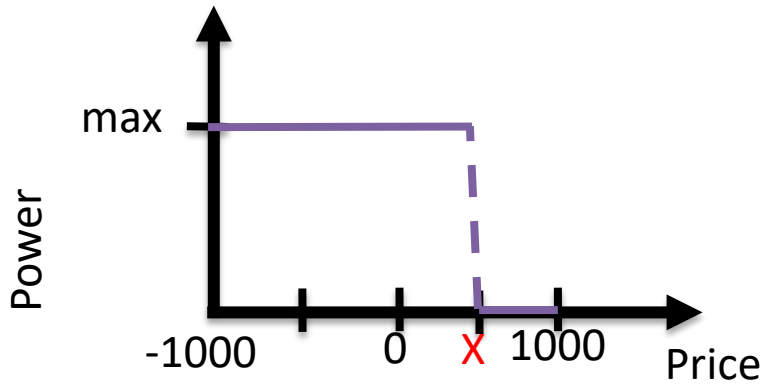


Modification of demand function

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

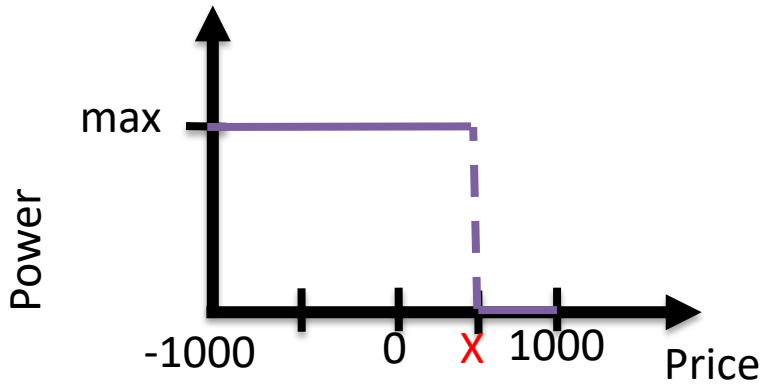
$$dT = 2 * hysteresis$$

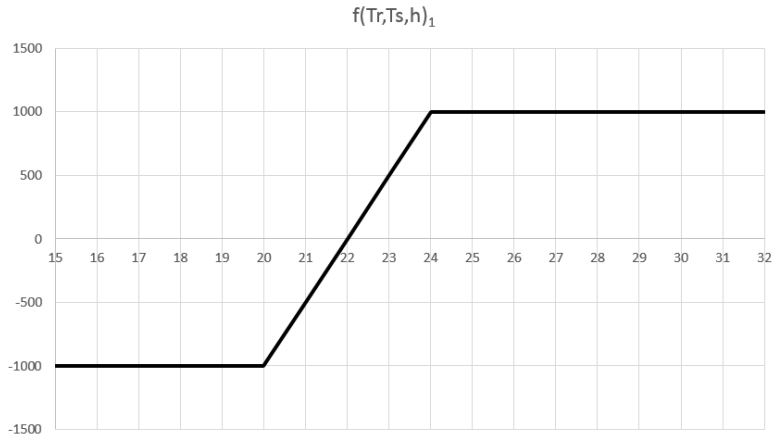
$$X_1 = -1000 + 1999\left(\frac{T_r - T_s}{dT}\right)$$

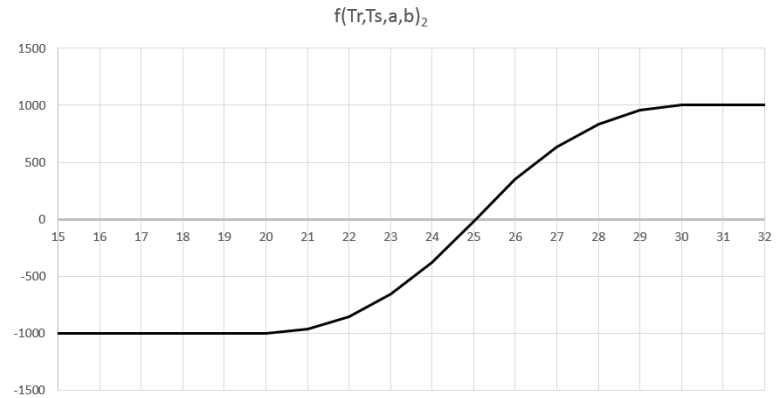


$$X_2 = \begin{cases} 0, & x \le a \\ 2\left(\frac{x-a}{b-a}\right)^2, & a \le x \le \frac{a+b}{2} \\ 1 - s\left(\frac{x-b}{b-a}\right)^2, & \frac{a+b}{2} \le x \le b \\ 1, & x \ge b \end{cases}$$

Modification of demand function







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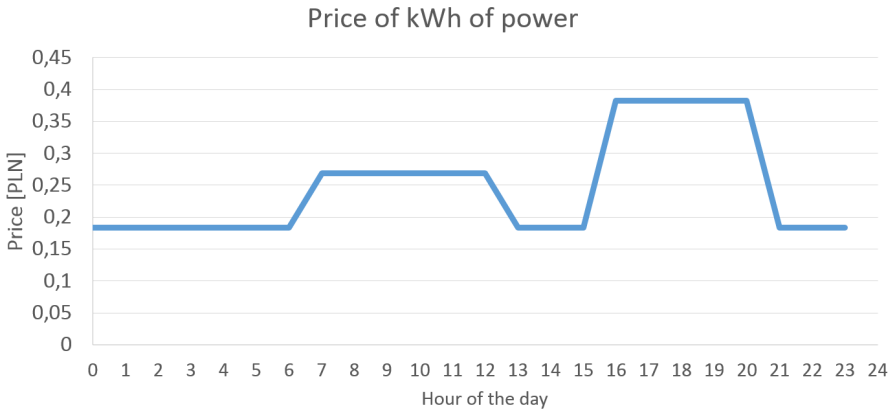
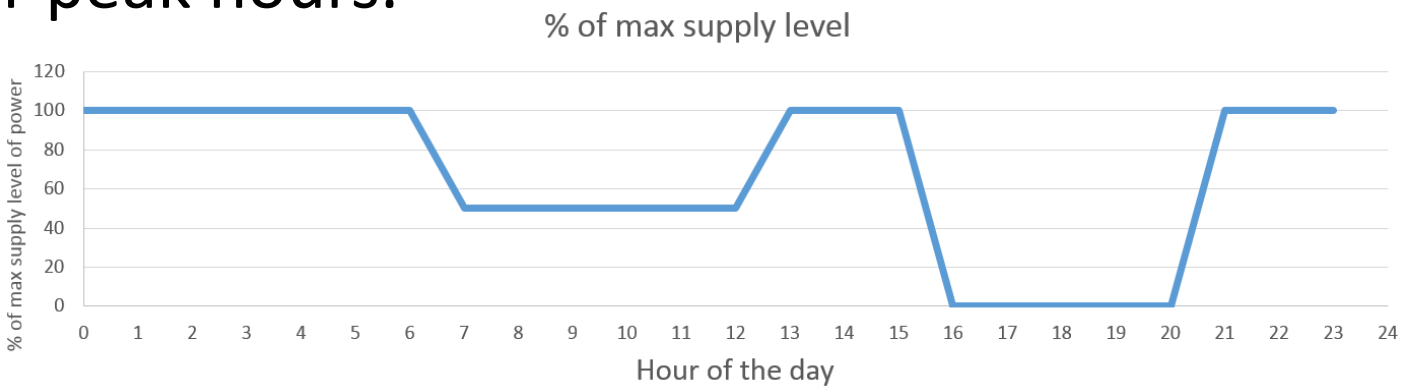
Maximum supply level

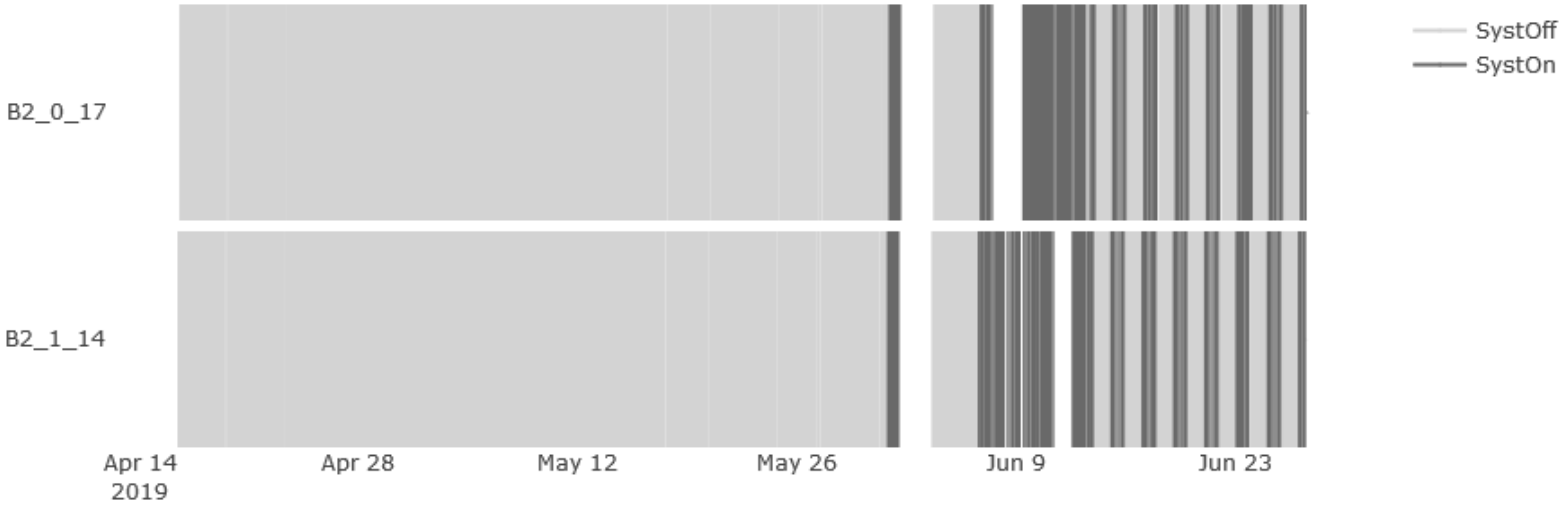
- The amount of supplied power is determining the clearing price.
- The limits were imposed based on the general averages for peak hours.





Experiments setup

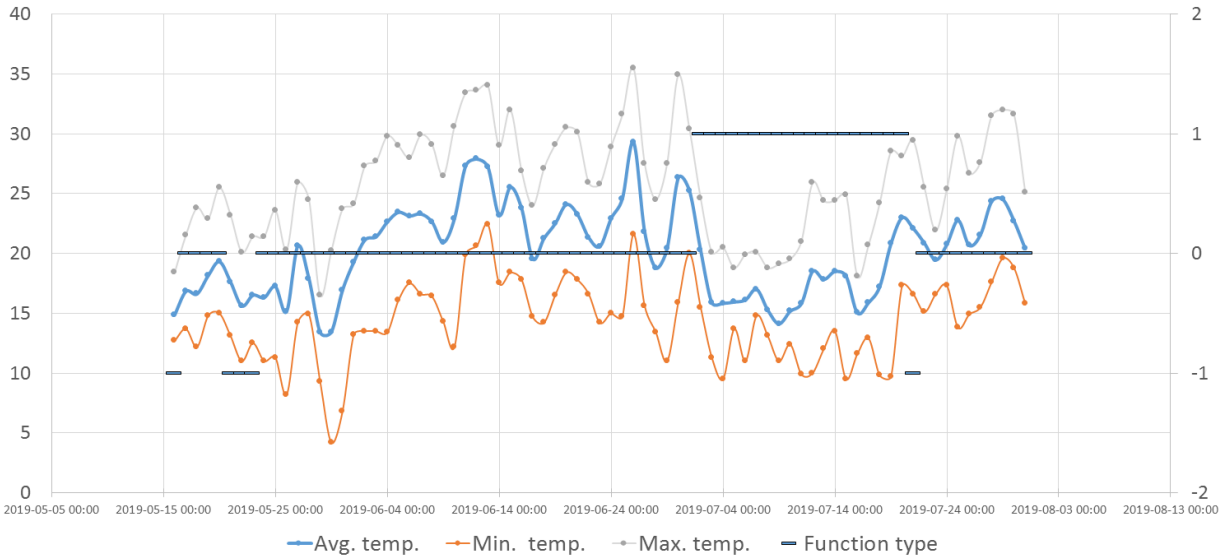
- Case 1: basic operation of the pumps based only on temperature.
- Case 2: operation with automatic system with cost function 1.
- Case 3: operation with automatic system with cost function 2.
- Case 4: operation with automatic system with limited power.



Operation of heat pumps

Problems:

- Temperatures – difficult to find very similar days.
- Missing values – investigation is still on-going.



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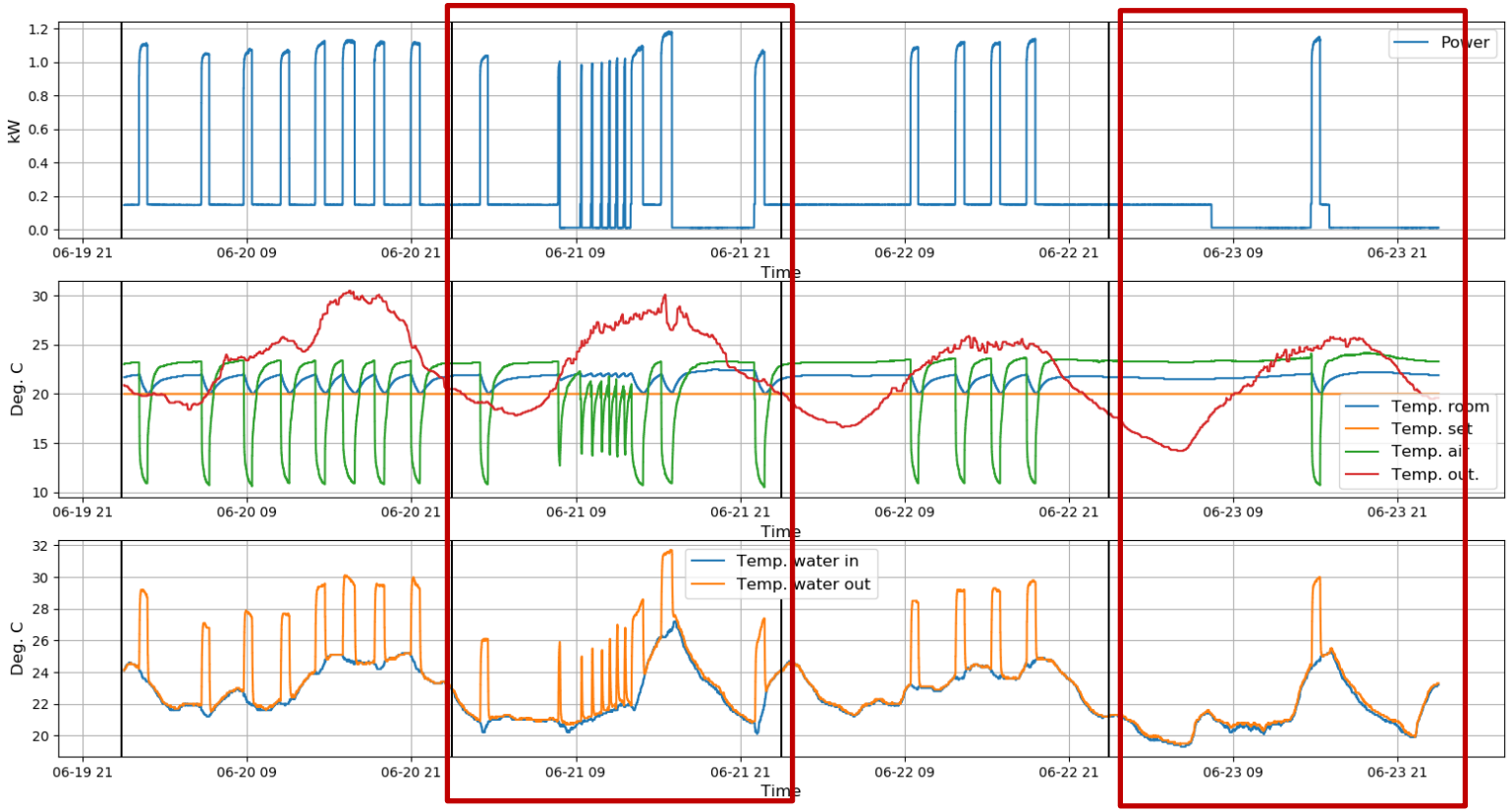
2019-06-20 — 2019-06-23 – B2-1-14



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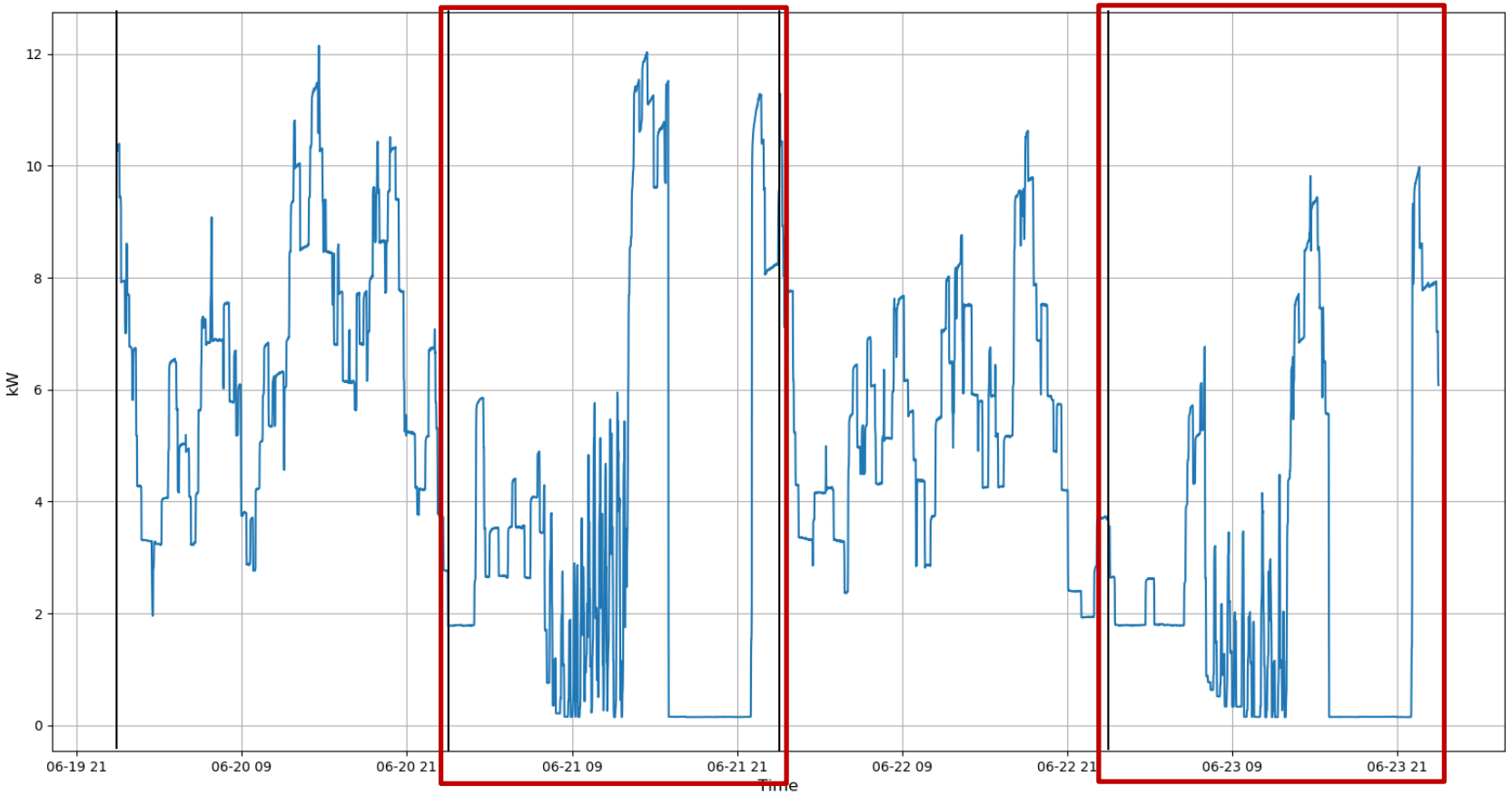
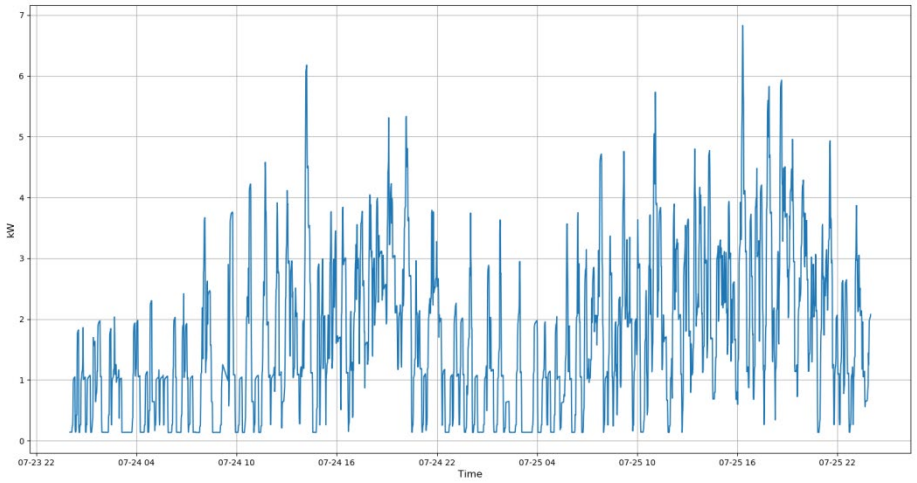
2019-06-20 — 2019-06-23 – sum of power

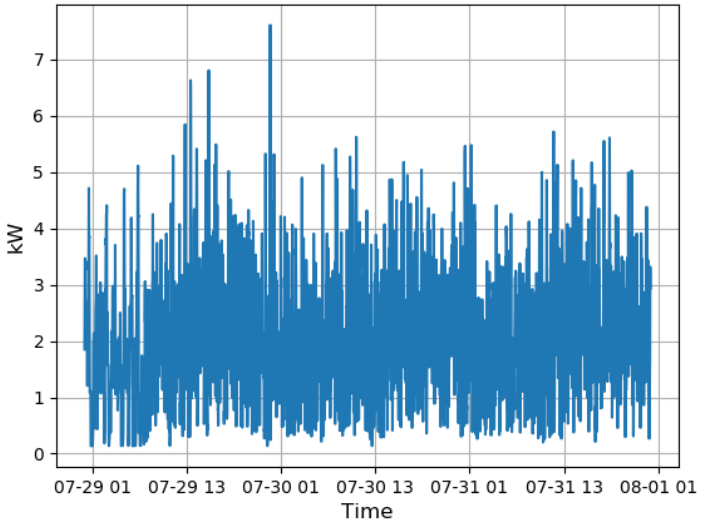


Limiting the peak power

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.