District heating system sate analysis by anomaly and flexibility detection based on state estimation, measurements and simulation for system evaluation with quantified and qualified data

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Motivation

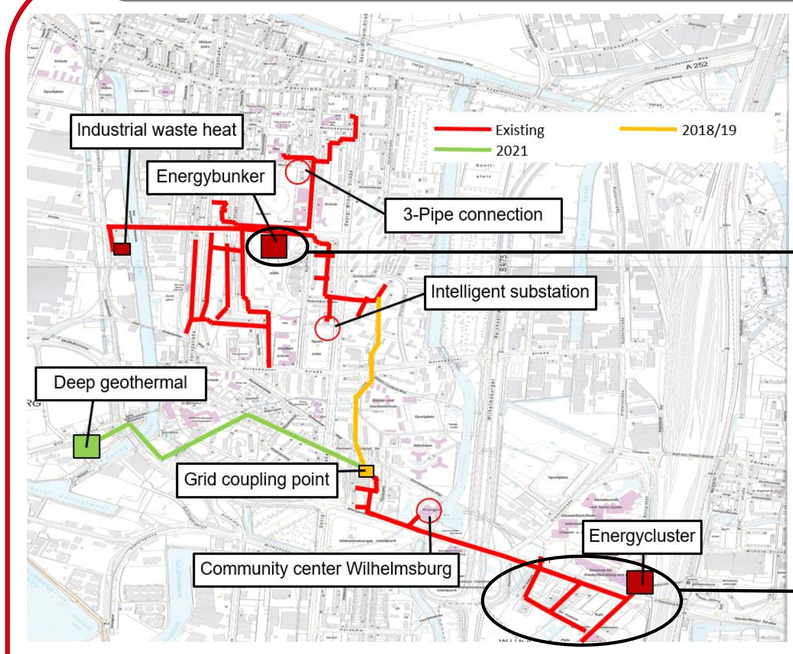
International climate goals until 2050 (Paris Agreement)

- Energy Turnaround 2050
- 80 % renewable electrical generation
- Reduction of primary energy demand in the heat sector by 80 %
- Flexible and Efficient heating sector

- Integrated energy systems
- Smart grids
- Smart thermal systems
- Efficiency (CHP), reduced heat demand, integration of renewables, sectional coupling

Key developments:
Concepts for measureable and controllable district heating sysmtes elements
Means for evaluation and analysis of district heating system operation

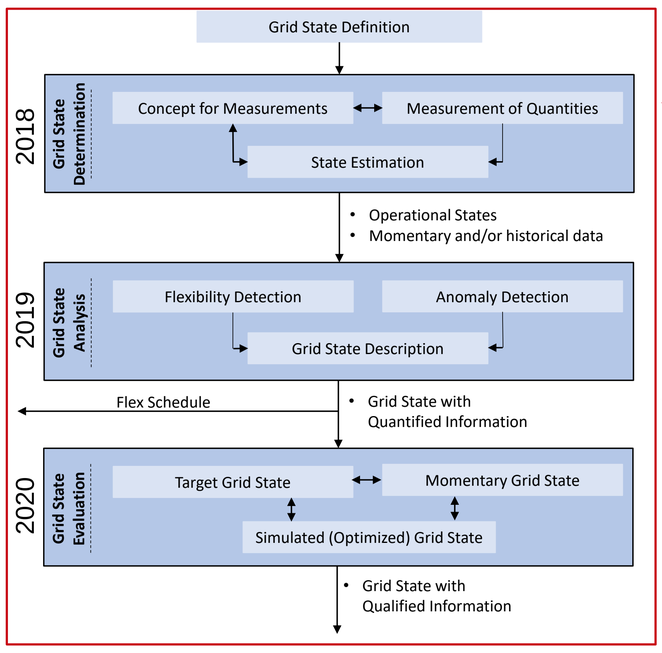
Background and research object



DHS Hamburg Wilhelmsburg

Lot of data is gathered within operation but tools for analysis and evalutation are missing.

Objectives and interconnection



Foundation

Research Project Smart Heat Grid Hamburg (SHGH) — Upgrade existing 3rd gen. DHS to 4th generation

Collaboration

PhD Peter Lorenzen — Flexibility concepts and operation

Foundation

Research Project Smart Pro HeaT — Building automation and smart home for DHS

Goals: Reduce amount of sensors and increase each sensors value.

Definition and state determination

Definitions

- **A state** is the particular condition that someone or something is in at a specific time. [1]
- **The state in thermal systems** depends on the physical quantities temperature, flow and pressure.
- **A state description** in a technical environment uses physical quantities and (differential) equations.
- **The operational state in a district heating system** is separated into control areas (e.g. one substation). The operational state itself is the result of control strategies reacting to physical quantities in the system. Inappropriate reactions to physical quantities are anomalies or failures.
- **The grid state of a district heating system** combines operational states of all control areas.

Approach for first estimator

Now

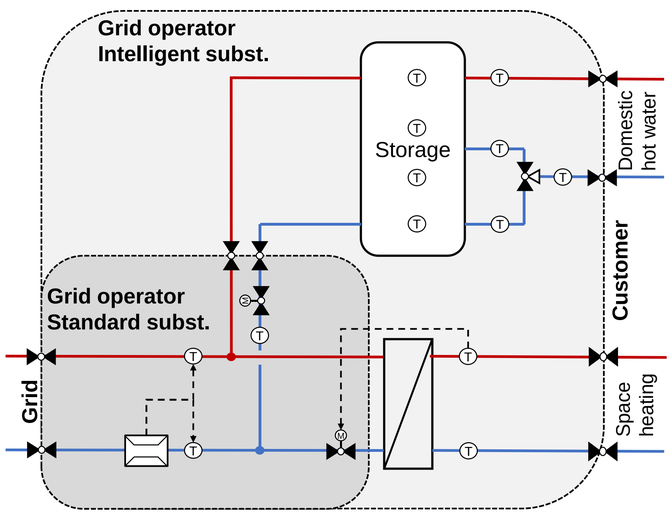
System description and definition	Creation of a usable dataset	Estimation concept and implemenation	Estimation concept for larger grid parts
• Intelligent substation or power house (data quality) • Include system decoupling (storage and heat exchanger)	• Grid data for defined system (Hype) • Store in own timeseries database (Influx, Jarvis dataminer)	• Modelling (discrete) • State estimation with Kalman-Filter • Validation with grid data	• Aggregation from control area over subsystem to grid • Jarvis integration (SHGH)

[1]: Oxford University Press: *English – Oxford living dictionaries.* URL: https://en.oxforddictionaries.com/definition/state (Last access: 10.05.2018)

Constructive concept – intelligent substation

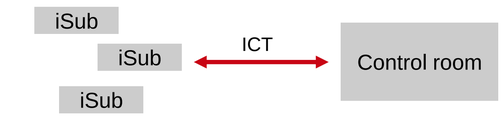
Hydraulic design

Substation with domestic hot water



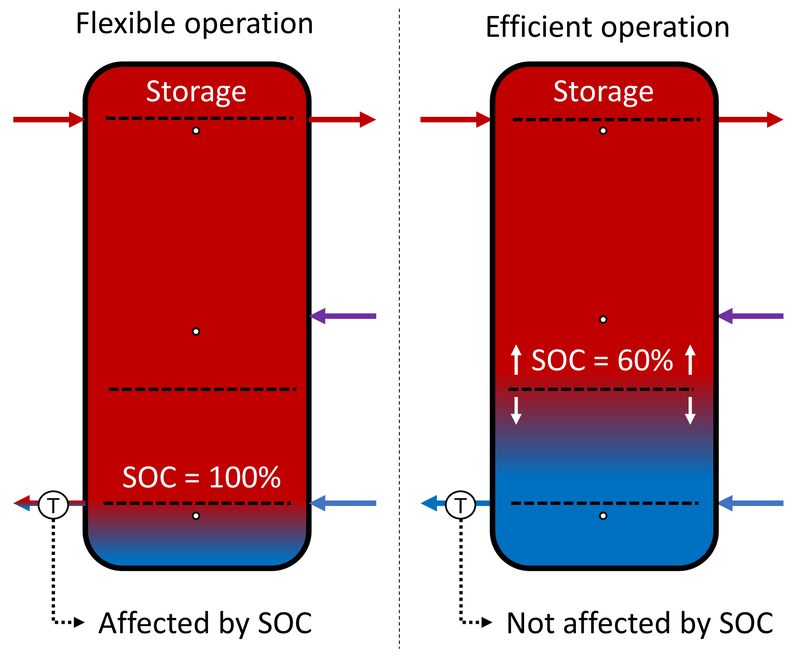
Goal: Create measureable and controllable DHS components. These allow system analysis and evaluation.

Control strategies - Storage



- Initital operation
- Minimal temperature
- Lost communication
- Grid collapse
- Function check
- Load grid elemets
- Limit charging (return temp.)
- Limit power
- Cut charging (while circulation)
- Normal operation

Evaluation – control strategy “limit charging”



Charging a water based heat storage increases the return temperature.

The intelligent substation cuts charging as soon as the difference between return and flow temperature deceeds 10 K.

This control strategy reduces the usable capacity of the storage. → A tradeoff between flexilbity and effieciency arises.

Next steps

- Intelligent substation will be build, tested and simulated, control strategies will be adjusted.
- First state estimation approach in separated control area. Concept for transfer to larger grid.
- Continue development of anomaly detection and evaluation methods.

Side aspects

- Preparation of a paper as co-author for “International symposium of district heating and cooling”
- Pending PhD funding application at HUAS
- Pending project application “Smart Pro HeaT”: Smart Prosumer Heating Technologies, cooperation with Aalto University (Finland), 2,5 years, ≈1 Mio. €, up to two possible PhD projects
- Establishing a district heating research field at HUAS located at Energycampus Bergedorf

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