Munich Institute of Integrated Materials,
Energy and Process Engineering (MEP)
Technische Universität München

RESEARCH INTERNSHIP / MASTER THESIS

Intelligent Network Monitoring: Machine Learning for Efficient District Heating Network State Estimation based on Limited Measurements

Background

The decarbonization of the heat sector poses a central challenge for the future energy supply. Innovative district heating concepts can play a key role by enabling the integration of diverse and sustainable heat sources, efficiently utilizing synergies among network participants, and providing increased flexibility for the entire energy supply through coupling with the electrical grid. At our institute, we are researching the technical implementation and control of such innovative district heating networks. Our approach is twofold: on one hand, we conduct theoretical investigations based on modeling, simulations, and optimization; on the other hand, we carry out practical experiments in a unique multi-energy laboratory that replicates a neighborhood with five buildings.

One research focus is on innovative district heating and cooling networks of the 4th and 5th generation. A distinguishing feature of these networks are decentral prosumers that can feed-in or extract thermal energy from the network to optimize the power flows amongst the participants for maximum efficiency. This evokes bidirectional power and mass flows in the network, leading to new thermohydraulic challenges for the network operation.

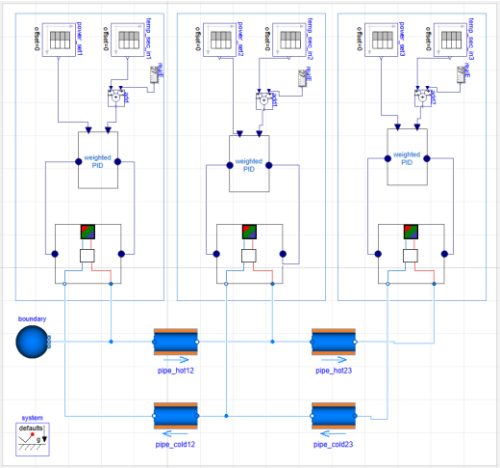

Figure 1: Network simulation with ProsNet in Dymola

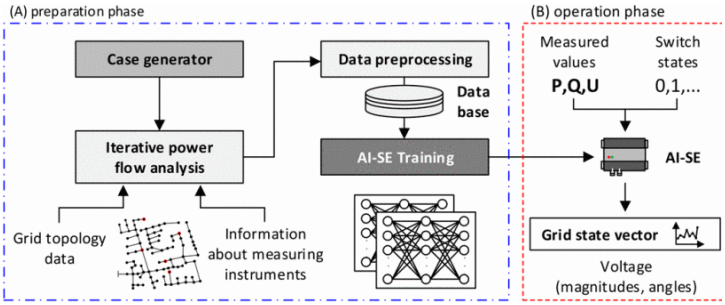

Figure 2: Structure of supervised learning for state estimation in electric distribution grids.

Topic

In conventional district heating networks, only few network-side measurements are taken, in particular at the hydraulic worst-point. Due to the simple functional principle and the steady operation of conventional networks, these few measurements are enough to operate the network with central pumping stations in the network. With an increasing penetration of prosumers, the network operation is decentralized to the substations and becomes much more dynamic and complex due to the mutual influence of the control actions. This makes it far more complex to anticipate the emerging system states. Comprehensive knowledge on the thermohydraulic state in the network at different locations becomes essential for a stable and smart network operation. As sensor equipment is expensive and prone to failure, one way to go is the estimation of the network state based on few local measurements. Due to the complexity of the thermal and hydraulic intercoupling of central and decentral actuators, physical models go along with high computational complexity. Additionally, they require high parametrization effort and are limited in the adaptation to changing network settings. Therefore, a machine-learning based approach for the grid state estimation during live-operation shall be developed and tested. Grid state estimation is an explored topic in electric grid operation, however new and innovative to thermal grids.

The topic comprises the following tasks:

- Familiarization with 4th and 5th Gen. District Heating and Cooling (DHC), i.e. the thermo-hydraulics behind it and refreshing knowledge on state estimation and machine learning methods
- Familiarization with existing DHC models in Dymola (Modelica), which are to be used for data generation and for testing in live-operation
- Literature review on preceding and related work
- Choosing a suitable ML approach and a development environment (e.g. Python, Matlab)
- Setting up a toolchain for the interaction of simulation environment and controller-environment
- Developing and training the state estimator
- Benchmarking the estimator against the ground truth of simulated values from models
- Result processing, evaluation and presentation
- Preparation of a report describing the key aspects and findings of the conducted work
- Disseminating clean source code via an open-source repository and presenting the results to a scientific audience

Literature for the start: Lickleder2021a, Winter2021, Lickleder2021b, Huang2012, Primadianto2016

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Interviews with applicants will be conducted mid of April,
Thesis starting date is around beginning of May 2024.