Set-Based Modelling of District Heating Networks

Collaboration with Stadtwerke München (SWM)

Background

District heating networks require careful operational control to simultaneously ensure high efficiency, reliable heat supply, and long-term asset integrity [1]. A central operational decision in such systems is the selection of the supply temperature. This parameter has a decisive influence on thermal distribution losses, pumping electricity consumption, and the aging of network components. Lower supply temperatures reduce heat losses and mitigate material degradation; however, they also decrease the temperature difference between supply and return lines. To deliver a given thermal power under these conditions, higher mass flows are required, which increases pumping effort and is ultimately constrained by the installed pump capacities.

Operational complexity is further increased by the substantial transport delays inherent in district heating networks, which may span several hours between a temperature change at the feed-in point and its effect at consumer substations. Consequently, supply temperature decisions must be made in advance of the actual heat demand. If the selected supply temperature is too low and mass flow limits are reached, hydraulically disadvantaged consumers may experience under-supply due to insufficient differential pressure. Preventing such situations requires reliable forecasts of future heat demand. These forecasts must explicitly account for uncertainties arising from incomplete or heterogeneous measurement data, as well as from changing operating conditions.

Description

The objective of this thesis is to develop set-based forecasting models for heat demand in a real district heating subnetwork in collaboration with the Stadtwerke München. The proposed approach relies on novel set-based identification methods [2, 3] that allow model uncertainty and data imperfections to be represented explicitly in the model.

For consumers with sufficiently rich measurement data, individual heat demand models will be identified directly. For consumers with limited or incomplete data availability, existing data enrichment and estimation techniques will be applied and, where necessary, further developed. The resulting individual consumer demand forecasts will be aggregated to estimate the total heat demand at the feed-in point, explicitly accounting for mass-flow-dependent transport delays within the network. The resulting set-valued demand forecasts will be implemented in the operator's IT environment and may optionally be coupled with an existing digital twin of the network to assess and compare alternative operating strategies in advance.

Tasks

- Familiarization with the structure and operation of district heating networks.
- Analysis of available measurement data, data interfaces, and data quality, including assessment of existing demand estimation methods.
- Application and adaptation of novel set-based identification methods to construct consumer-level heat demand models.
- Aggregation of set-valued consumer demand forecasts to the feed-in point, considering mass-flow-dependent transport delays.
- Implementation and validation of the forecasting models in the operator's IT environment, optionally in combination with the digital twin.

References

[1] Dennis Pierl, Kai Vahldiek, Julia Koltermann, Bernd Rüger, Kai Michels, Frank Klawonn, and Andreas Nürnberger. Exploiting synergies of data-driven and model-based approaches for leakage localization in district heating networks. In *International Symposium on District Heating and Cooling*, pages 495–502, 2023. https://www.iea-dhc.org/fileadmin/public_documents/DHC2023_Conference_proceedings_CDHA.pdf.

[2] Laura Lützow and Matthias Althoff. Reachset-conformant system identification. *IEEE Transactions on Automatic Control*, pages 1–16, 2025. https://ieeexplore.ieee.org/document/11250664.

[3] Laura Lützow, Michael Eichelbeck, Mykel Kochenderfer, and Matthias Althoff. Zono-conformal prediction: Zonotope-based uncertainty quantification for regression and classification tasks. *Accepted at Journal of Machine Learning Research*, pages 1–34, 2025. https://arxiv.org/abs/2508.11025.

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Industry partner:
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Type:
Bachelor's or Master's Thesis

Research area:
district heating networks, system identification, reachability analysis

Programming language:
Matlab and Python

Required skills:

- strong mathematical background
- experience with system theory (e.g., control theory, system identification)
- programming experience

Language:
English, German

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