PhD Public Defence

Title: Conversion of Existing District Heating Grids to Low-Temperature Operation and Extension to new Areas of Buildings

Location: Pontoppidanstræde 105 room 3.115

Time: Thursday 6 October 2016 at 13.00

PhD defendant: Soma Mohammadi

Supervisor: Associate Professor Carsten Bojesen

Moderator: Associate Professor Tom Condra

Opponents: Associate Professor Henrik Sørensen, Dept. of Energy Technology, Aalborg University (Chairman)
Senior Researcher Hongwei Li, Technical University of Denmark, Kgs. Lyngby, Denmark
Director Robin Wiltshire, Heatmatters Ltd., UK

All are welcome. The defence will be in English.

After the defence there will be an informal reception in Pontoppidanstræde 111 (coffee room).
Abstract:

In order to overcome the growing concern regarding energy and environment problems, it is necessary to increase the share of renewable energy sources in energy systems. In Denmark, 2035 is the target for being 100% independent of fossil fuels in both electricity and heating sectors. The flexibility of district heating systems concerning the choice of heat source makes district heating an inevitable part of the future sustainable energy system; however, the existing district heating systems need to pave the way for low-temperature operation to be fitted to future low-energy buildings and sustainable energy systems’ requirements. These changes are defined under the concept of 4th generation district heating systems where the main focus is on lowering the supply temperature level. Reducing the heat losses in the distribution network, as the main sources of heat losses in district heating systems, is a crucial challenge, which will lead to improving the energy efficiency and the prospect of utilizing low-grade heat sources and renewables in district heating systems. Several operational and design strategies have been discussed in the literature for reducing the heat losses and temperature level in district heating networks. However, finding the most energy-efficient strategies to fit a district heating network depends on different factors including network size, network structure, pipe geometry, consumers’ heat demand, etc. And it raises the necessity of performing a critical analysis accounting for district heating network characteristics beforehand. The focus of this study is on developing a tool to satisfy this demand.

A thermal-dynamic modelling tool is developed where the dynamics of both the consumers and the distribution networks are addressed due to their strong effects on the network operational performance and heat losses. Besides modelling district heating network operational performance, the developed tool provides a platform to evaluate and analyse the influence of implementing alternative strategies on district heating networks’ performance. The MATLAB programming language is used to make the tool. In order to develop this tool, a physical method is used where a detailed model of the network structure is designed and the district heating network components are included. To model the transient effects, the pseudo-dynamic approach is applied in which the flow and pressure are calculated based on a steady-state model and the temperature changes are modelled dynamically.

Given the network input variables, comprising the pipe network data, the network structure, the time series consumers’ heat demand and return temperature, the time series supply temperature to the network and the time series data related to the surrounding soil temperature, the network hydraulic calculation is performed initially. The next step is modelling the transient heat transfer in the pipes where the finite element method and implicit numerical method are adopted. The model outputs are the mass flowrate at each consumer, the mass flowrate in the pipes, and the supply temperature at the primary side of the consumers’ substation in regular time intervals as well as the flowrate passing through the thermal bypasses. The developed tool is applied in performing a thorough heat loss analysis of a district heating pipe network where the heat losses caused by the thermal bypass operation are considered by proposing a method for modelling this operation.

To validate the model’s accuracy, the model was run during one year’s operation of a district heating network in the Studstrup area, Denmark, where 321 consumers are connected to the district heating network through 14 km supply and return pipes. The obtained results were then compared with the real-life measurements. The results confirmed the precision of the developed tool for thermal-dynamic modelling of district heating networks. To present the model’s competencies, two scenarios are deployed. The first scenario looks at refurbishment of an existing district heating network concerning the choice of pipe types and insulation. The second one evaluates the implementation of three design concepts in
building an energy-efficient district heating network accounting for district heating network operating temperature level and pipe dimensions. Besides modelling DHN operational performance, the developed tool in this study is applied to assess the feasibility of performing alternative operational strategies and design concepts in both existing and new district heating networks. Furthermore, developing a tool in MATLAB provides an open platform to make further improvement to and integration with other parts of district heating systems.