The Development of a New District Heating Concept - DTU Orbit (12/08/2019)

The Development of a New District Heating Concept: Network Design and Optimization for Integrating Energy Conservation and Renewable Energy Use in Energy Sustainable Communities

PART I of this doctoral thesis consists of 6 chapters.

Chapter 1 summarizes the main issues caused by the use of energy resources. They involve ecological, economic, demographical and socio-political topics that are linked together and define the background of the thesis.

Chapter 2 describes the state-of-the-art of District Heating (DH) systems, with focus on the present and future situation in Denmark.

The core of the thesis consists of the development of a new DH paradigm, the “Low-Temperature District Heating (LTDH)”, the study of its potential, and investigations of technical options which improve its applicability in terms of energy performance and socio-economy. Chapter 3 describes the whole idea about LTDH.

Chapter 4 presents the hypotheses of the studies, draws the boundaries between the focus area of the thesis and other relevant aspects of the subject, describes the limitations of the work and lists the methods which were used.

Chapter 5 explains the results of the scientific content reported in the articles in PART II. Article I introduces the technical and organizational strategies that can facilitate the establishment of a successful energy planning in a community. It analyses the state-of-the-art in community energy planning, discusses critical issues, and points at the role of DH in moving towards sustainable heat supply. The articles II and III aim at providing science-based knowledge for the development of improved solutions for the DH networks; they focus on the performance simulation of DH pipelines through models for assessing the energy performance of innovative pipe geometries, materials or system configurations. The models were validated against experimental measurements on real DH pipes. Article II considers the detailed steady-state modelling and analysis of heat losses in pre-insulated DH pipes. Article III focuses on the modelling and computation of the transient heat transfer in service pipes, which are important elements of LTDH networks, particularly when supplying low heat density building areas. The purpose of article IV was to perform simulations and analyses about low-energy DH networks supplying heat to energy-efficient building areas in countries – such as Denmark – with an extensive existing DH infrastructure, quantify their technical and economic feasibility, and suggest strategies for optimizing their design and operation. Article V deals with the potential and barriers of implementing DH in Canada, where the DH market share is low. Technical-economic feasibility studies for DH networks supplying an urban area in the city of Ottawa were carried out, with particular attention to developing the potential for supplying heat derived from Renewable Energy (RE).

Chapter 6 summarises the conclusions. First of all, analysis of the case studies suggests that local authority energy plans should take the opportunities for DH implementation into account, because DH is an essential infrastructure for future, sustainable energy systems. Energy policy should aim at organizing and facilitating the synergy between energy conservation measures and the supply of heat based on RE energy and overcome the traditional competition between the two sectors. It is recommended that Finite Element Method (FEM) models and simulation should be used when designing new pipe geometries and systems. The reliability of the FEM models of DH pipes was validated by means of experimental data and comparison with analytical formulas and data from literature. The calculation method takes into account the temperature-dependency of the thermal conductivity of the insulation foam. It was demonstrated that the asymmetrical insulation of twin pipes in low-temperature operations leads to 4% to 8% lower heat loss from the supply media pipe than a symmetrical configuration, and at the same time the heat loss from the return media pipe can be kept close to zero. With the use of optimized double-pipe systems (a pair of differently-sized media pipes, embedded in the same insulation and casing pipe), it is possible to cut heat losses by 6% to 12% in comparison to twin pipes without increasing investment costs. Finally, the development of an optimized triple pipe solution is described.

The code modelling the transient heat transfer in DH service pipes is proven to be accurate, since it gives results that well represent the outlet temperature profile measured in the experiments with deviations of less than 0.5°C, and it is in good accordance with detailed, finite-volume simulations, for both stepwise and sinusoidal boundary conditions with regard to the inlet temperature profile. The proposed integrated solution consisting of service pipe and heat exchanger unit with a booster pump satisfies the requirement for DHW supply within 10 seconds and achieves heat savings for 200 kWhth/yr with an additional electricity use of approximately 58 kWhel/yr.

In Denmark, optimally-designed LTDH networks can be cost-effective in areas with a linear heat density as low as 0.20 MWh/(m.yr). For the cases considered, the levelized cost of energy is between 13.9–19.3 c€/kWh (excl. VAT) and this is approximately 20% lower than the scenario based on ground-source heat pumps. The network designs based on low-temperature operation are superior to the design based on lowflow operation. The total primary energy use in the most energy-efficient design is 14.3% lower than in standard networks and the distribution heat losses are halved. The results indicate that the LTDH concept fits the vision of the future energiesustainable heating sector in Denmark.

In the investigations of the case studies in Canada, it was found that DH supply to building areas with linear heat density greater than 3.0 MWh/(m.yr) is competitive with the natural gas supply alternative and offers the opportunity to implement the use of RE and low-grade heat sources. The areas with linear heat density below 1.5 MWh/(m.yr) are not economically feasible with the current situation of the energy market in Canada, but could be considered for future network extensions together with the implementation of improved design and planning concepts. Moreover, medium-temperature DH networks can be designed for current heating loads while envisaging low-temperature operation in the future.

General information
Publication status: Published
Organisations: Department of Civil Engineering
Contributors: Dalla Rosa, A.
Number of pages: 254
Publication date: 2012