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Evaluation of the temperature regimes of multi-level thermal networks in urban areas through exergy analysis

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Abstract

The overall objective of this study is to explore the potentials of district heating systems (DHS) operating on more than two high temperature levels. This characteristic allows integrating decentralized and renewable thermal energy sources. It also enables the network to minimize inefficiencies caused by mismatches between supply and demand exergy levels. This paper studies the effects of better suited exergy levels for DHS with two, three and four supply temperature levels. It is shown that having more than two temperature levels is in many cases advantageous both exergetically and economically.

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Keywords: Multi-level thermal network, Exergy analysis, Low-Temperature district heating

1. Introduction

District heating systems provide a useful platform to integrate renewable heat sources as well as combined heat and power units (CHP). Thermal networks can therefore be implemented for future sustainable heat supply compared to the individual heating systems. Increasing the efficiency of the district heating systems is the subject of many research and development projects. Reducing the inefficiencies due to high temperatures is a key concern for

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improving thermal networks. The benefits of lowering the temperature in district heating systems include different aspects, such as reduced network heat loss [1,2], improved power to heat ratio in the CHP plant [3,4] and facilitated integration of renewable energy sources [5] and waste heat [6]. Furthermore, low temperature regimes allow DHS supply to low heat density areas and are more appropriate for the future low energy buildings [7,8]. However, most of the studies regarding lower temperatures in thermal networks are concerned with newly built areas. The existing district heating systems deliver heat to a variety of building types with different energetic characteristics. Supply temperature in these systems is usually high in order to meet the demand of the buildings with highest temperature demand. Therefore, the temperature regimes are unnecessarily high for many buildings connected to the network. This fact becomes increasingly important, due to refurbishment measures and more strict regulations for buildings. Reducing the temperature regimes in district heating systems is in line with the LowEx approach, which addresses the utilization of low exergy levels for heating applications in buildings [9]. This paper analyses the effect of the mismatch between the supply and demand temperatures from the exergetic viewpoint. The thermodynamic irreversibility caused by the difference between the exergy of the delivered stream and the actual needed exergy is calculated in terms of exergy destruction during the heat transfer process. The results are transferred to a sample district in Berlin with different types of buildings. Together with economic investigations it is then concluded that having a DHS with more than two temperature levels can be favourable both exergetically and economically. An algorithm is used to transfer the results to arbitrary areas with similar consumer characteristics in central Europe.

2. Methodology

Dynamic thermal energy simulations are conducted with the object-oriented programming language Modelica. It is assumed that the system is an indirect district heating network, which means that a heat exchanger separates the heating medium of the network from the one of the building. Exergy analysis is a useful approach to determine the thermodynamic losses of a process or a system. Irreversible thermodynamic processes cause exergy destruction within the system. Since the heat transfer process is one of the most common causes of thermodynamic losses, exergy analysis is used to determine the value of the exergy destruction in the heat transfer process of the DHS. In order to investigate the effects of better suited exergy levels of the supply and demand sides on the exergetic efficiency of the system, the choice of an appropriate system boundary is important. Figure 1 shows the chosen boundary in this study. The temperature of the system boundary is assumed to be the same as the temperature of the thermodynamic environment, which is the widely used 20°C for simplicity. Therefore, there is no exergy stream associated with heat transfer to the environment and the exergy loss is zero. In order to calculate the exergetic efficiency of the system, the resource expended to provide the required heat is considered to be the heat delivered on the primary side and the desired product is defined as the heat received on the secondary side of the heat exchanger. The delivered and received exergies are respectively identified as the exergy of fuel and exergy of product as in [10].

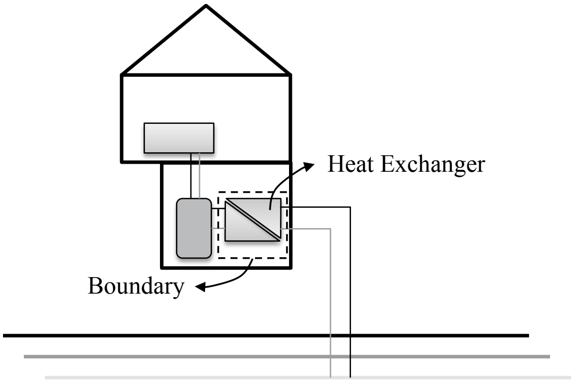

Figure 1. Chosen system boundary for exergy analysis