Dimensioning radial prosumer-based thermal networks

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Conventional thermal networks are characterized by central generation units transferring heat to consumers with a unidirectional mass flow driven by central pumps. The integration of prosumers increases energy efficiency and flexibility. In this paper we consider the most flexible form of prosumer integration: a thermal network that comprises only prosumers without any dominating central unit. Decentral actuators (pumps and control valves) in the substations enable bidirectional mass and energy flows in the network for load-balancing between prosumers [1]. The question arises of how to dimension such networks.

Due to the unidirectional flows in conventional networks, each network section (pipe, substation) is part of a fixed hydraulic circuit (see fig 1, A and B). The worst conditions for each network section in its hydraulic circuit build the design state for dimensioning. However, in prosumer-based networks, each specific network section is part of varying hydraulic circuits. This is caused by bidirectional flows in the network and influenced by changing prosumer modes and load situations (see fig. 1, C and D). Therefore, to dimension each network section, its individual hydraulic circuit with the worst conditions must be determined. Since conventional dimensioning procedures do not consider changing hydraulic circuits, we developed a rule-based method for dimensioning prosumer-based networks.

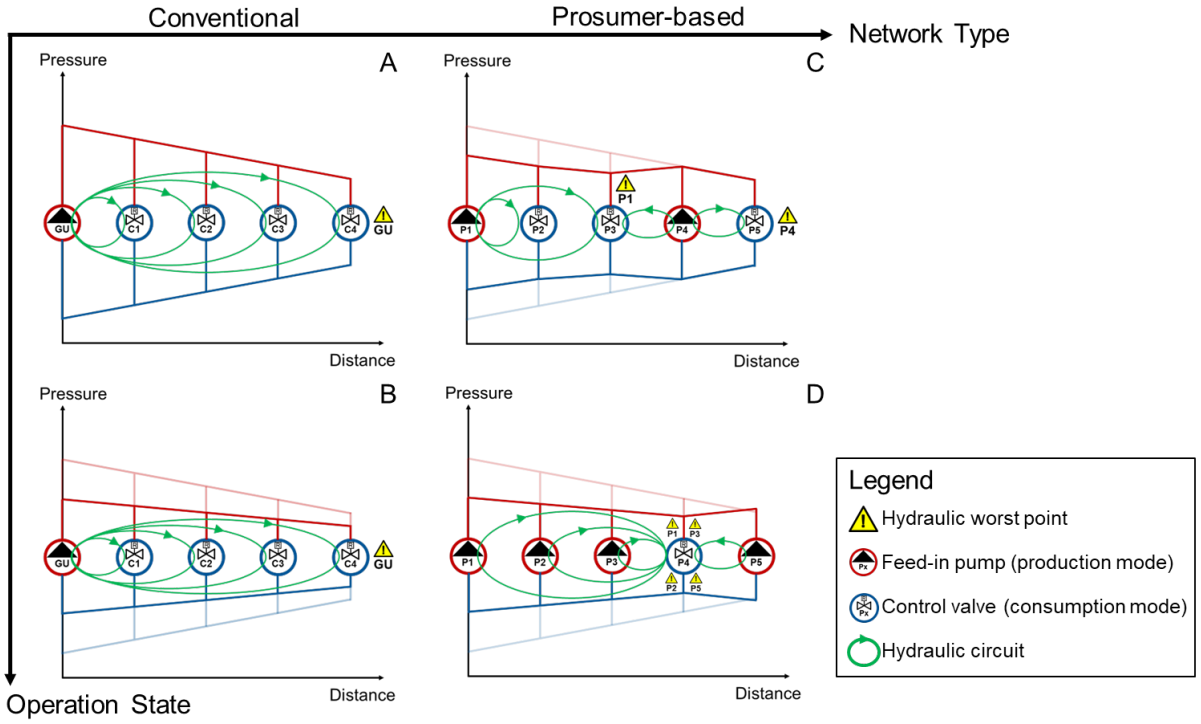

Figure 1: Comparison of pressure curves and hydraulic circuits in different operation states of a conventional network (A and C) with central generation unit vs. prosumer-based network (B and D). In conventional networks the hydraulic circuits are fixed, while in prosumer-based networks they change depending on the operation mode.

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We propose a method to identify relevant design conditions for each network section in radial prosumer-based networks. This method requires specifications on the maximum feed-in and extraction power of each prosumer, a design network temperature difference, maximum flow velocity, hydraulic pipe resistances per unit length, and targeted valve authorities. Furthermore, two design premises are considered:

- All-Neighbor-Exchange (ANE): Energy exchange between all prosumers
- One-Neighbor-Exchange (ONE): Energy exchange only between directly neighboring prosumers

By determining the hydraulic circuit with the maximum combination of production and consumption for each network section, our method identifies maximum volume flows through each network pipe and substation. This is the basis for dimensioning all components (pipes, pumps, valves, heat exchangers) using adapted conventional methods.

The method is implemented in a dimensioning tool to automate the calculations. To illustrate the process and validate functionality, a case study is conducted. The case study is based on conditions and loads emulated in the CoSES laboratory [2], representing a small-scale residential district heating network. The dimensioning results from the tool serve as parameters for a dynamic simulation using the ProsNet [3] Modelica library. By analyzing the thermohydraulic network states, the functionality of the suggested design method is assessed. To check for overdimensioning, the operation states of the actuators in design conditions are evaluated.

Preliminary simulation results show plausible network behavior during example operation states. The heat demands of prosumers are fulfilled while the actuators operate close to their design point, indicating reasonable dimensioning.

Overall, we propose and validate a method to easily dimension the main components of radial prosumer-based networks in early design stages. Two design premises give upper and lower boundaries for component dimensioning depending on the targeted operation flexibility. Like this, economic comparisons for variant decisions early in a project become easier and more consistent.

Literature

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Keywords

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