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Smart district heating networks – A simulation study of prosumers' impact on technical parameters in distribution networks

Lisa Brand [a,b,*], Alexandra Calvén [a,b], Jessica Englund [b], Henrik Landersjö [b], Patrick Lauenburg [a]

[a] Energy Sciences, P.O. Box 118, SE-221 00 Lund, Sweden
[b] E.ON Värme Sverige AB, Flintrännegatan 19, 211 24 Malmö, Sweden

HIGHLIGHTS

- A district heating network with decentralized solar collectors was simulated.
- Contribution from solar collectors may result in lower supply temperature locally.
- Contribution from solar collectors may result in increased flow velocity locally.
- Contribution from solar collectors may change the differential pressure locally.
- Pipes near the solar collectors will not be influenced by increased fatigue.

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ABSTRACT

Environmental awareness increases, with demands for environmental certifications of new communities and buildings as a result. In the district heating industry, enabling of decentralized energy production is one way to meet requirements from customers. In this paper the technical impact of small-scale local solar collectors and heat pumps on district heating distribution networks is investigated. Customers that in this way can both produce and consume district heating are in this paper called prosumers. The study has mainly been performed through simulations in the computer programme NetSim. The results show that since the supply temperature from prosumers often is lower than the typical supply temperature, contribution from prosumers may result in lower supply temperature and thus increased velocity. The differential pressure decreases when water from the prosumers is mixed with supply water from the rest of the network and increases in the area where the prosumer creates a new pressure cone. Areas that are not reached by water from prosumers are affected differently depending on how the control of the differential pressure is managed. The results also show that prosumers' lower supply temperature may cause migratory temperature fronts that lead to increased fatigue in the pipes. This was further investigated by the local district heating company and the result showed that migratory temperature fronts generally has little impact on the lifetime of the pipes, since corrosion remains to be the limiting factor. In summary, this paper indicates that introduction of prosumers is possible, but demands management and control.

1. Introduction

The energy sector is responsible for a large part of the increasing emissions of greenhouse gases [1], why development of green energy solutions is of great importance. Many recent studies address the future role of renewable energy in district heating systems. For examples, Sperling and Möller describe end-use energy savings and district heating expansion in a local renewable energy system [2] and Ghafghazi et al. analyse different energy sources available for a district heating system in Vancouver [3]. Other studies deal with the role of district heating in future renewable energy systems [4] and the technology and potential enhancements of district heating and cooling [5]. According to Rezaie and Rosen [5] and Lund et al. [4], the share of renewable energy in the future district heating systems will increase. A recent publication discusses terminologies related to smart district heating network such as smart thermal grids, smart energy systems and 4G

* Corresponding author at: Energy Sciences, P.O. Box 118, SE-221 00 Lund, Sweden. Tel.: +46 462223320.

E-mail addresses: lisa.brand@energy.lth.se (L. Brand), alexandra.calven@hotmail.com (A. Calvén).

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Nomenclature

c_p	specific heat (kJ/kg °C)
d	diameter of pipe (m)
L	length of pipe (m)
$\dot{m}$	mass flow rate (kg/s)
P	heat power (kW)
T_r	return temperature (°C)
T_s	supply temperature (°C)
v	velocity (m/s)

Greek

ρ	density (kg/m^3)
Δp	differential pressure (Pa)
λ	friction factor (–)

district heating [6]. Especially interesting for the present study is the emphasising of the importance for district heating systems to be able to receive low temperature heat from i.e. central or local solar collectors in order to fulfil its role in a future sustainable energy system. Renewable heating sources are also discussed in a newly released paper that adds a European level to other papers listed regarding the future role of district heating [7].

District heating customers request the possibility to deliver excess heat from private heat production to the district heating network and thus become decentralized micro producers. The produced heat often comes from utilising renewable energy systems, for example solar collectors. A customer that both produces and consumes district heat is, in this paper, called a *prosumer*, an expression already used in the power sector [8]. More prosumers in the district heating network requires a transformation of today's networks into smart district heating networks, which puts pressure on energy companies to enable this. This is described in a report by Ottosson et al. [9], which describes future development of district heating networks. In a paper written by Nielsen and Møller [10], the impact of excess heat from solar collectors from net zero energy buildings on a district heating system, from a heat production point of view, is investigated. Environomic optimisation of decentralized heat pumps is investigated in a paper written by Molyneaux et al. [11]. Several publications have discussed solar heating in district heating systems considering large-scale solar heating systems, often in combination with thermal energy storages, in Germany [12], in Canada [13], in a model with 100 well insulated housing units [14] and in a report focusing on large solar heating and cooling systems [15]. Others have described district energy systems in combination with heat pumps [16,17,11,18]. There are also publications that are handling different aspects of low temperature district heating networks, such as DHW preparation with respect to service pipes [19], substation types and network layouts [20], dimensioning of piping networks and network layouts in low energy district heating systems connected to low-energy buildings [21], and energy and exergy analysis [22].

As can be seen, there are a lot of publications discussing how future district heating systems may look like, with respect to for example supply temperature and thermal storages. Other papers address energy profiles and large scale solar heating systems. It is obvious that renewable energy in district heating production could be of great importance in future district heating systems. This renewable energy could consist of for instance large scale solar heating systems and heat pumps, which are also widely discussed in scientific publications, as discussed above [11–18]. At the same time, experience from district heating companies shows that customers are getting increasingly environmentally aware and thus demand the possibility to utilise their own renewable energy. This makes also decentralized small scale renewable energy, such as small scale solar collectors and heat pumps, an interesting topic. There should be no technical problem of introducing such facilities in low temperature district heating networks, which are also discussed in the scientific literature. There is however a great lack on publications, in scientific journals, describing how the technical parameters in the district heating networks of today will react to the applications of tomorrow. A process of redirecting the present district heating networks to low temperature district networks will be slow and probably costly, but it is comparatively easy to install e.g. solar panels or heat pumps. Therefore, there will probably be, and are already, such installations in conventional district heating networks. Since introduction of prosumers to a district heating network will affect both the network itself and its customers, it is important to study prosumers' impact on the network. This paper aims to look into this question and thereby help to address the lack of knowledge in this area.

This paper focuses mainly on the following questions:

What impact does the introduction of prosumers have on technical parameters, such as supply temperature, flow rate, velocity and differential pressure?

What should be considered when requirements on prosumers, regarding heat power and supply temperature, are formulated?

The study was performed at E.ON Värme Sverige AB in Malmö, Sweden.

There are several driving forces to introduce prosumers into district heating networks. An example is laws and regulations to which energy companies have to adjust. Some EU directives aim to decrease the environmental impact of the energy sector and are of great importance since EU directives have effect on the national laws of the member states [23]. Sweden has several laws and 16 environmental goals [24], which have impact on the district heating market. Another driving force is the requirement for environmental classifications of buildings, for examples by BREEAM or LEED [25].

This study was conducted in a district heating simulation programme called NetSim [26]. The input data was mostly obtained from the local district heating company. Data regarding the future solar collector production was obtained from a solar energy calculation programme called WinSun0709. The study focused mainly on the district Western Harbour (Västra Hamnen) in Malmö, Sweden. The heat pump simulations were mainly conducted to see if the results of the solar collectors could be applied to heat pumps, but the focus has mainly been on solar collectors, since heat pumps are more easily controlled.

1.1. Local characteristics

The Western Harbour is a recently built area in Malmö, with a district heating network that is a part of the district heating network in Malmö. The conventional heat generation system in Malmö consists mainly of combined heat and power based on natural gas, waste incineration and excess heat from a nearby factory. The hydraulic separations in substations consist of indirect space heating and closed hot water supply and the district heating network provides heat for both domestic hot water and space heating needs. This is the most common solution in Sweden [27].