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ScienceDirect

Energy Procedia 96 (2016) 511 – 516

Energy Procedia

SBE16 Tallinn and Helsinki Conference; Build Green and Renovate Deep, 5-7 October 2016, Tallinn and Helsinki

Cost Analysis of In-House Heat Substations in Next Generation Heat Networks

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Abstract

Lowering the district heating supply temperature is crucial for improving the efficiency of the heat network. A developed concept of fourth generation low temperature district heating with supply temperature just above the required end user conditions allows for heat loss reduction, increases the plant room efficiency and enables the integration of alternative energy source for heat production. Due to the lowered temperature approach the cost of the in-house substation increases. This paper presents analysis of the cost increase of the in-house heat substation to enable the cost-benefit analysis of next generation district heating systems while considering new and refurbished systems. Heat transfer calculation software tool has been used to analyse the cost increased of the substation due to required high performance of the plate heat exchanger while considering that the rest of the components are the same model/size, including heat meter, control valve and pipework. It is concluded in this paper that by an accurate design of the in-house systems it is feasible to provide a cost effective solution of in-house heat substations operating in next generation heat networks.

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Peer-review under responsibility of the organizing committee of the SBE16 Tallinn and Helsinki Conference.

Keywords: *district heating; low temperature; heat substation; heat exchanger*

1. Introduction

The heat network supply temperature is the parameter that significantly affects and limits the efficiency of the district heating system, therefore a concept of fourth generation heat network has been developed, where the primary supply temperature is lowered to below 55 °C. This increases the efficiency of heat networks by reducing the distribution heat loss and allows the implementation of renewable and low carbon emission energy source. The

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Peer-review under responsibility of the organizing committee of the SBE16 Tallinn and Helsinki Conference.
doi:10.1016/j.egypro.2016.09.093

supply temperature reduction is limited to a temperature that will ensure that the end-user's space heating and domestic hot water comfort as well as sanitary requirements are met. A number of fourth generation heat network pilot projects have proven that the district heating supply temperature can be reduced to 55 °C and kept low all year around without sacrificing the end-user's comfort [1]. This requires the use of low temperature heat emitters and efficient heat substations for domestic hot water production.

To allow for the reduction in supply temperatures in fourth generation heat networks, the reduced flow and return temperature approach is required across the plate heat exchanger used in the in-house heat substation. The minimum domestic hot water supply temperature is typically required by the national standard, due to the threat of Legionella bacteria outbreak. The minimum hot water temperature is defined in Danish Standard 439 as 50 °C allowing the temperature to drop to 45 °C during peak periods. [2] German Technical regulations DVGW 551 makes no requirement if the overall hot water volume is below 3 liters [3]. British Standard BS 5885 requires 50 °C delivered to the hot water outlets or thermostatic mixing valves [4].

Previous studies of hot water production in low temperature heat networks are based on 'the rule of 3 liters' [5], however in this paper, the minimum hot water temperature is assumed to be 50 °C to reflect current requirements in heat substation design.

In-house heat substations are designed to provide hot water and heating typically for a single family home. In this study three scenarios have been considered for the peak domestic hot water draw off at 10, 12 and 14 liters per minute at 50 °C and the cold water temperature is assumed to be 10 °C.

Nomenclature

Δp	total primary side pressure drop of the heat substation, kPa
LMTD	logarithmic mean temperature difference in heat substation, °C
ΔT_A	flow temperature approach of the heat substation, °K
ΔT_B	return temperature approach of the heat substation, °K
w	weight increase ratio of the plate heat exchanger
v	volumetric size increase ratio of the plate heat exchanger
f_{HS}	cost increase ratio of the in-house heat substation

2. Methods

To establish the cost increase factor, the following steps have been outlined.

2.1. Reference and analysis condition selection

Current heat networks in Europe operate with supply temperatures of up to 110 °C in winter and 65 °C in summer depending on the local conditions. The report summarizing research findings of existing heat networks in United Kingdom established that existing networks can deliver required end user heating and domestic hot water demand with supply temperature of 70 °C [6] also meeting the maximum safe supply domestic hot water temperature that can be set as a minimum by national standards. The guidelines [8] would advise to have a low return temperature of 25°C when supplying hot water. Therefor the reference primary flow and return temperature conditions for the domestic hot water plate heat exchangers are selected to be 70/25°C. This condition is used to determine the size and weight increase of the plate heat exchanger.

The published literature on fourth generation heat networks define the primary temperature as 55 °C or lower and secondary temperature of 50 °C or lower. This study will analyse the heat substation design with the lowered flow and return approach temperatures between 1 and 5 °K. The resulting logarithmic mean temperature difference LMTD is used to demonstrate and compare the conditions reviewed:

$$LMTD = (\Delta T_A - \Delta T_B)/(\ln \Delta T_A - \ln \Delta T_B) \qquad (1)$$

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