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Return Temperature in DH as Key Parameter for Energy Management

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ABSTRACT: *Decreased supply temperature of district heating networks gives a number of system's advantages, like increased overall efficiency, possibility to use renewable energy resources and decreased heat loss from the district heating network. To ensure the appropriate heat supply to the customers and avoid large pipeline diameters, it is important to keep the temperature difference as large as possible. Therefore the return temperature of the district heating network should also be decreased. When supply and return temperatures are lowered, the district heating network is more sensitive to the temperature difference faults, making fluctuations in the temperature graphs. Due to this fact it is important to predict behavior of district heating system's temperature difference, depending on the outdoor temperature.*
KEYWORDS: *District heating, temperature difference, supply temperature*

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I. INTRODUCTION

The latest type of district heating systems called 4th generation is characterised by being a part of the long term infrastructure planning, leading to smart heat distribution network with low supply, return temperatures and integrated renewable sources [2].Today the district heating system represents the high efficiency and environmentally friendly heat and hot water supply to the highly populated areas. The key aspect of the system is to supply otherwise wasted heat to the customers, by using the heat distribution network of pipes [1].

According to [3] the share of the district heating (DH) in the EU heat demand covers approximately 13% and has a tendency to increase by the transition to a low-CO2 energy system, utilising renewable energy resources and operated at lower supply and return temperatures. The decrease of network temperatures is considered as one of the key factors to increase the efficiency of the new DH systems [3].

Lowering the supply temperature of the DH network gives several advantages [2, 4], e.g.: increased heat recovery from the energy production units like boilers and CHP-plants; utilisation of renewable energy resources; as well as increased electrical output from CHP-plants. As it is shown in [3] if supply temperature is lowered from 80 ^{0}C to 40 ^{0}C and the return temperature is lowered from 60 ^{0}C to 30 ^{0}C, the efficiency of heat production increases by approximately 10 % in solar thermal plants and 30 % in heat plants operated by heat pumps.

Recent studies [4-5] have indicated that even relatively low supply temperatures (slightly above 50 ^{0}C) can meet consumers' demands for Central and Northern European countries. The decreasing of the heat supply temperature in a district heating network allows achieving lower heat losses and higher efficiency of the entire system.

II. LITERATURE REVIEW

The supply and return temperatures in district heating systems play a crucial role in efficiency of such systems. According to [3] district heating systems can be divided into 4 groups, depending on the supply temperature. High temperature DH systems are characterised by the temperature between 100 ^{0}C and 120 ^{0}C and are used very random. The most commonly used systems are so-called medium temperature DH, having the supply temperatures between 65 ^{0}Cand 95 ^{0}C. Further decrease of the supply temperature feasible and reasonable but it requires additional investments into district heating water (DHW) systems due to the eventual grow of Legionella bacteria.

Decreased supply temperatures of the DH networks require larger network diameters, and result in higher pumping costs in order to ensure the sufficient flow. To avoid that, it is also necessary to lower the return temperature and keep the temperature difference between supply and return flows as large as possible [4].

During the heating season, the district heating supply temperature closely correlates with the outdoor temperature in order to provide the optimal comfort conditions for the inhabitants. Johansson et al. [6] reports the strong correlation between measured outdoor temperature and the heat load. As it was noticed in [4], during the heating season the space heating dominates in the building's heat demand, resulting into temperature difference between supply and return temperatures inversely proportional to outdoor temperature. As soon as the space heating loses its dominating role, no general correlation between temperature difference and outdoor temperature is observed.

Theoretically the supply and return temperatures of the DH network should fluctuate only due to fluctuations of customers' demand. In reality the temperatures of DH network are influenced by both the changes in customers' demand and the temperature difference faults [4]. Very frequently the temperature difference faults would lead to increased return temperature of DH network and results into increased supply temperature [4], as the temperature difference between the supply and return temperature should be kept constant. Due to this fact it is very important to predict the pattern of the temperature difference of the DH network, thus allowing to estimate and exclude the temperature difference faults in much shorter time.

The difference between supply and return temperatures ΔT usually varies during the year. Empirical study in [4] showed that correlation exists between temperature difference ΔT and outdoor temperature T_{out} during heating season in Denmark. The trend line showing the decrease of ΔT as T_{out} increases is presented in [4] for the case T_{out}<10 ^{0}C. For larger values of the outdoor temperature the data are scattered over a wide range of values (from 0 ^{0}C to 50 ^{0}C) and no correlation exists beyond T_{out}>10 ^{0}C.

Since there are some differences in heating systems' operation in Denmark and Latvia, the study has been conducted with the objective to obtain the relationship between temperature difference ΔT and outdoor temperature T_{out} for heating stations in Riga, Latvia.

III. RIGA DISTRICT HEATING SYSTEM

The district heating system in Riga city is operated by the JSC „Rīgas siltums" [7]. The company provides heat for space heating and hot water from several boiler plants and heating stations located in Riga city. The two largest heating stations TEC1 and TEC2 have been selected for the study for two heating seasons 2015/2016 and 2016/2017, respectively.

The installed heat capacity at the heating plant TEC1 reaches 490 MW, while the heating station TEC2 is the largest cogeneration plant in Latvia, having the installed heat capacity of 1 124 MW including the hot water boilers.

The heating season in Riga city lasts from October until the end of April. During the heating season of 2015/2016 the amount of heat produced in TEC1 and TEC2 reached 782 GWh and 1154 GWh correspondingly. The produced amount of heat during the next heating season has increased due to the low outside temperature and extended heating season in the spring of the year 2017, reaching 842 GWh for TEC1 and 1289 GWh for TEC2. It should be noted that the connected heat load for the heating area of TEC1 and TEC2 is 960 MW at the winter temperature of -20.7 ^{0}C.

The total length of DH network in Riga city is 800 km, while the heat supplied from TEC1 and TEC2 is delivered by 557 km long network with the total volume of 117 462 m^3, ensuring the heat for 5515 customers. Both networks are interconnected and are able to provide heat for the same heating area or they can be split in order to ensure heat supply into two separate regions.

In order to measure the heat flow in the network, the measuring devices are installed at the end of main pipelines. The measuring devices consist of flow meter, integrator and temperature sensors for supply and return flows. The flow meter is installed on the supply pipe and it generates impulses proportional to the water flow. The integrator makes the data processing and collecting. The temperature difference is calculated and multiplied by the water flow and correction coefficient in order to take into account the density of the water and its heat content.

Fig.1 shows very similar pattern of the temperature graphs for supply and return temperatures in correlation of the actual outside temperatures for both heating stations TEC1 and TEC2 for the heating seasons 2015/2016 and 2016/2017. The significant increase of the supply temperature is required for the outside temperature below 3 ^{0}C, Fig1 and Fig2.

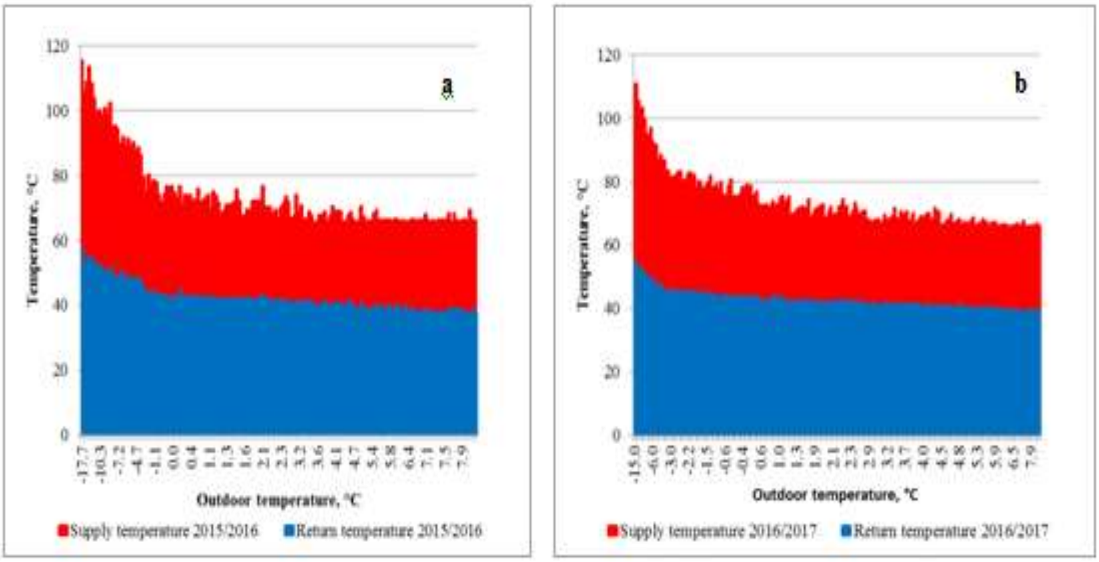

Figure 1: Supply and return temperatures in correlation of the actual outside temperatures from TEC1 for the heating seasons 2015/2016 (a) and 2016/2017 (b).

Similar trend has been observed for the heating network from TEC2, see Fig 2. The temperature patterns slightly deviate. It is in correlation with the idea (GADD) that every case has slightly different and specific temperature graph.

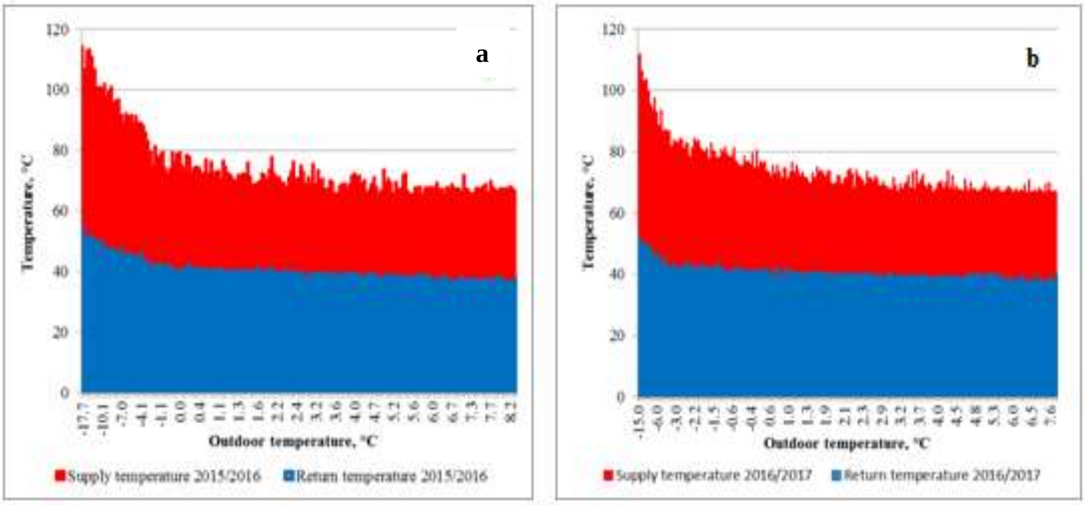

Figure 2: Supply and return temperatures in correlation of the actual outside temperatures from TEC2 for the heating seasons 2015/2016 (a) and 2016/2017 (b).

The average supply temperature during the heating season depends on outdoor temperature and reaches approximately 72 ^{0}C, while the return temperature is at 41 ^{0}C.

In order to evaluate the correlation between supply and return temperature difference and outdoor temperature, the calculations have been performed by using the software program Matlab. The results for the heating station TEC1, see Fig 3, show the strong correlation between supply and return temperature difference ΔT and outdoor temperature T_{out}, when the outside temperature is below 3 ^{0}C.

Gadd and Werner [4] noticed that in Denmark a strong correlation exists between temperature difference ΔT and the outdoor temperature T_{out} in the range of -20 ^{0}C< T_{out}<10 ^{0}C, but for higher outdoor temperatures ΔT is practically independent on T_{out}. As it is shown in [1], for T_{out}>10 ^{0}C the temperature difference temperature difference is widely scattered in the interval (0 ^{0}C, 50 ^{0}C). Similar trend has also been observed in DH network in Riga. The main difference from the data presented in [4] is that the correlation between temperature difference and outdoor temperature becomes independent already when the outdoor temperature exceeds 3^0C.

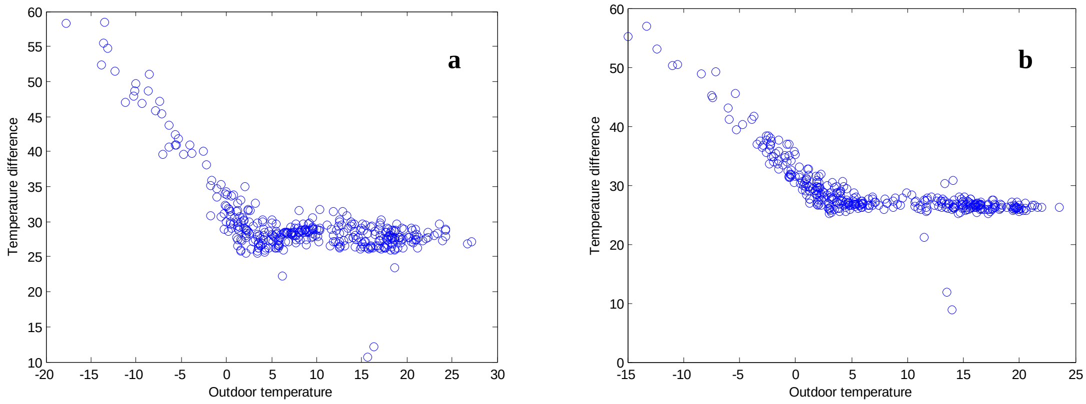

Figure 3: Temperature difference (ΔT) versus outdoor temperature (T_{out}) for heating station TEC1 in Riga during one year 2015/2016(a) and 2016/2017(b).

Since the correlation between ΔT and T_{out} exists, a regression analysis has been performed by fitting the data set for heating seasons in 2015/2016 and 2016/2017, using a second degree polynomial. The calculation results are shown in Fig. 4 and Fig. 5, where the best-fit second-degree polynomial and the corresponding data points are plotted from both heating stations.

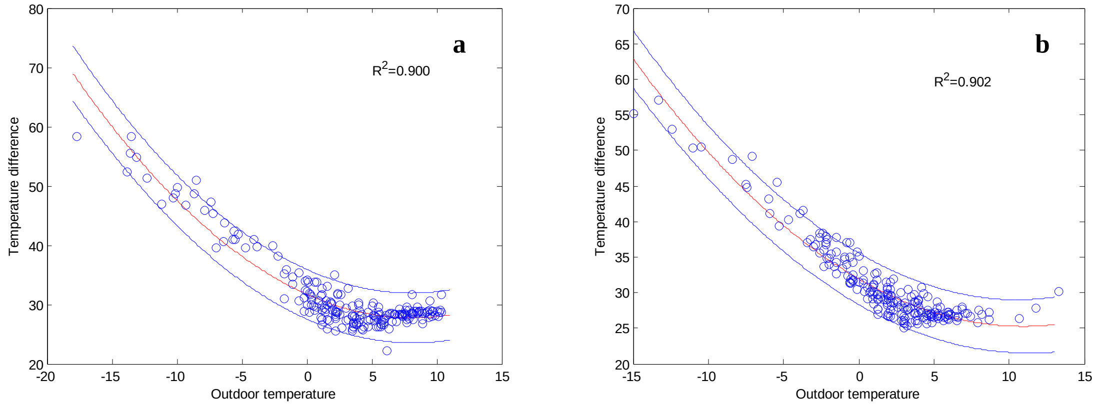

Figure 4: The best-fit second-degree polynomial and data points from the sample for the heating station TEC1 for heating season 2015/16(a) and 2016/17(b).

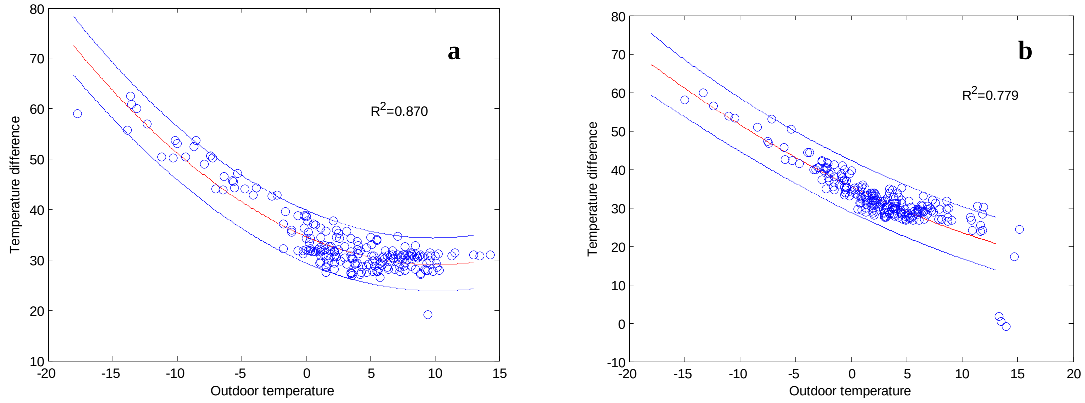

Figure 5: The best-fit second-degree polynomial and data points from the sample for the heating station TEC2 for heating season 2015/16(a) and 2016/17(b).

The analysis shows that the second-degree polynomial fits all the data well, as the coefficient of determination varies from 0.779 to 0.902. The corresponding p-values reported in Matlab are smaller than 10^{-4}

in all the considered cases. Almost all data points in Figs. 4, and 5 lie between the upper and lower bounds of the 95% confidence intervals.

IV. CONCLUSION

The regression analysis used to evaluate the DH network supply and return water temperature difference on the outdoor temperatures show that the curves above and below the graphs of the second-degree polynomial in Figs. 4 and 5 correspond to 95% confidence interval for the main predicted values.

As can be seen from Figs. 4 and 5, the typical difference between the upper and lower confidence interval limit is about 9^0C. The 95% confidence interval estimates to provide much smaller uncertainty than the estimates based on three standard deviations from the trend line [4].

As suggested in [4], such graphs can be used in order to identify faults in district heating systems, as the location of an observed data point outside the confidence interval limits may indicate on a fault in the DH network system.

The obtained analysis is one of the first steps towards the online fault analysis of the DH network.

There is a potential of decreasing the supply and return temperatures of the DH network in Riga city and transform the network into more efficient and sustainable one.

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