CONVERSION OF EXISTING DISTRICT HEATING TO LOW-TEMPERATURE OPERATION AND EXTENSION OF NEW AREAS OF BUILDINGS

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Outline

- Why Low-Temperature District Heating
- Existing District Heating Networks
- By-pass Application in existing district heating Networks
- District Heating Networks Simulation
- Real-Life District Heating Network

Why Low-Temperature District Heating

- Because of increasing the number of low-energy and energy renovated buildings
- Because of the growing demand for increasing the share of renewable energy sources and waste heat

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Introducing 4th generation of District Heating is key

(Supply and return temperature 55°C and 25°C respectively)

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- Reduce Heat loss in District Heating System
- Increase Combined heat and Power plant, power generation capacity and Utilize direct flue gas condensation for waste heat recovery

Existing District Heating Networks

In order to implement low temperature district heating concept in existing network, there are two situations needs to be considered:

- Peak-heat load periods/Heating season

- Low-heat load periods/non-heating season

Peak-load periods

Problem:

lowering the temperature may cause costumers dissatisfaction at peak-demand periods in order to provide their space heating demand.

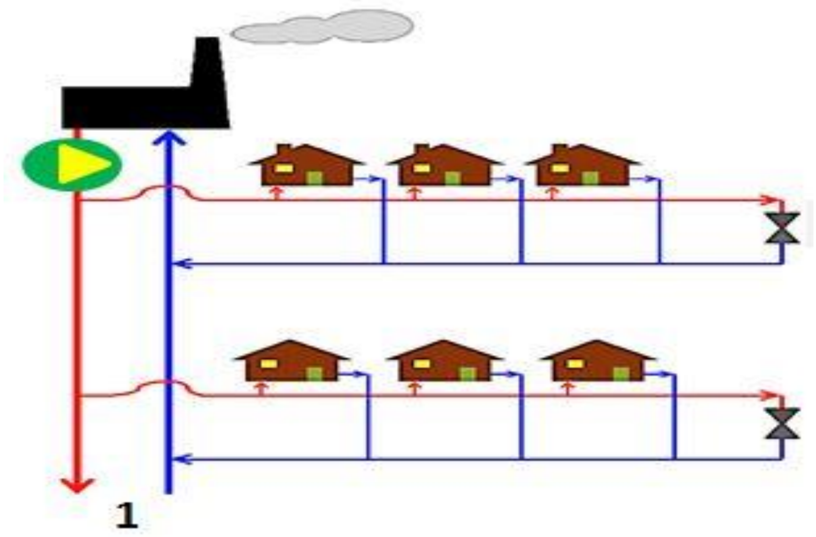
Proposed solutions:

- Increasing the supply temperature at high-demand periods
- local temperature boosting.

Low-heating load periods

Existing solution:

Currently **By-pass** is applied in district heating system.



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Main disadvantages in Existing By-pass

- Higher Heat Loss in the networks
- Increased return flow temperature
- Reducing Power generation capacity in combined heat and power plants
- The By-pass problem becomes more critical when it comes to low-energy buildings as the share of heat losses due to by-pass operation can be very high relative to their heat demand.

Recent Studies in By-pass application

- **By-pass water recirculation**

Network Design	Return temperature	Recirculated by-pass temperature	Heat loss
Reference scenario (Traditional DHN)	35.5C	-	12,78 kW
By-pass water recirculation (Summer time)	22C	44C	18 kW
Double pipe line supply (Winter time)	22C	-	**

**** double pipe supply leads to the highest network heat loss.**

However the conclusion regarding using double pipe can be drawn after further network thermal-economic optimization.

Recent Studies in By-pass application

- **Use of by-pass in bathroom floor heating-Continuous by-pass**

1. Techno-economic analysis of the use of by-pass flow in bathroom floor heating for low energy buildings
2. Modeling in house the space heating system

Results:

1. **Guarantee lowering the heat loss from the service pipes**
2. **Increase the thermal comfort outside the heating season in bathroom through floor heating wit very limited overheating problems**

Alternative By-pass strategies

- Local temperature boosting of domestic hot water by means electrical heater or heat pump
- Local heat supply from solar thermal system in the summer time

District Heating Modeling

The purpose of this study is:

To develop a flexible tool to calculate hydraulic and thermal behavior of district heating network.

in order to:

- Finding optimal supply temperature in an existing networks as a function of DHN heat loss, pump power demand and return temperature for a range of supply temperatures.
- The model is used for defining local temperature boosting as alternative strategy for by-pass application and at peak-load periods.

District Heating Modeling

- The model is developed in Matlab.
- It starts by developing a simplified model with a range of assumptions.
- The model is validated by applying for an existing real-life district heating networks.

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District Heating Networks Simulation

The model is based on a pseudo-dynamic approach whereas:

- The flow and pressure are calculated using a static flow model.
- The temperature is calculated dynamically depending on the flow velocity and several boundary conditions like soil and outside temperature.

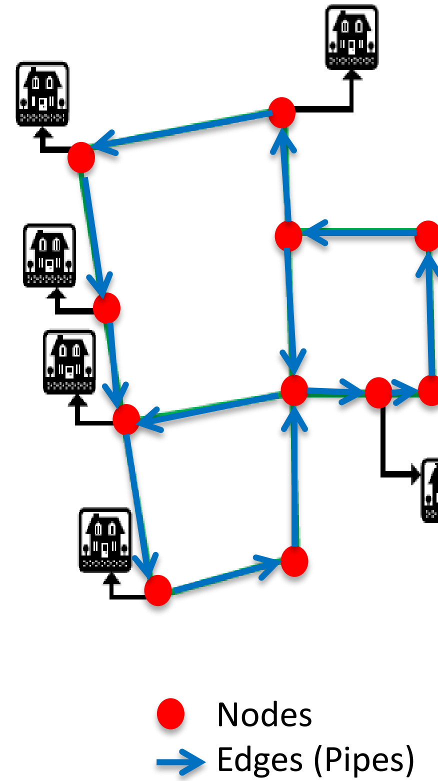
Main Assumptions:

- The fluid pipe flow is one-dimensional
- Turbulent fluctuations are not considered
- The network is free of leakage
- The fluid characteristics like density and heat capacity are constant

Hydraulic Calculation

Graph theory is considered to be the best tool for network analysis

- The DH system is considered as a collection of nodes connected by directed edges (pipes).
- The network graph in a matrix data structure containing the incidence matrixes and
- Matrix *A* associates each edge with its pair of nodes. Matrix *B* describes the location of the edges in each circuit.



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Hydraulic Calculation

Kirchhoff's circuit laws are applied to build the equations describing the flow rates and pressure losses in the network:

- The law of conservation of mass: the total amount of flow into one node is equal to the total amount of flow out of it:

$$A\dot{V} = 0$$

With the flow vector $\dot{V} = \{\dot{V_1}, \dot{V_2}, \dots, \dot{V_n}\}$

- The law of conservation of energy: the sum of all pressure differences along the edges of one circuit is equal 0:

$$B\,\Delta\mathrm{p} = 0$$

With the pressure difference vector $\Delta p = \{\Delta p_1, \Delta p_2, \dots, \Delta p_n\}$

*Darcy-Weisbach equation is used for pressure loss calculation.

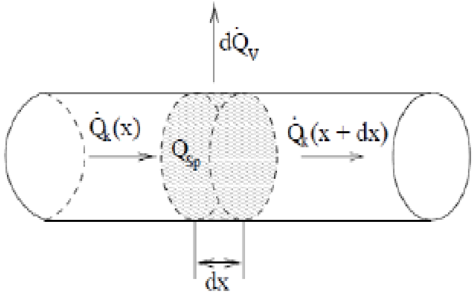
Thermal Calculation

Temperature propagation within one pipe:

$$Convective\ heat\ flow = \dot{Q}_K(x) = m_x . h = \dot{m}_x . c_p . T$$

$$Heat\ loss\ flow = d\dot{Q}_V = k . d_x . (T - T_{soil})$$

$$m c_p \frac{\delta T}{\delta t} = -\dot{m}_x . c_p . \frac{\delta T}{\delta x} . d_x - k . d_x . (T - T_{soil})$$



This partial deferential equation describes the temperature propagation in small element. Then the finite element method is applied to solve the equation and to obtain the temperature profile along the pipe.

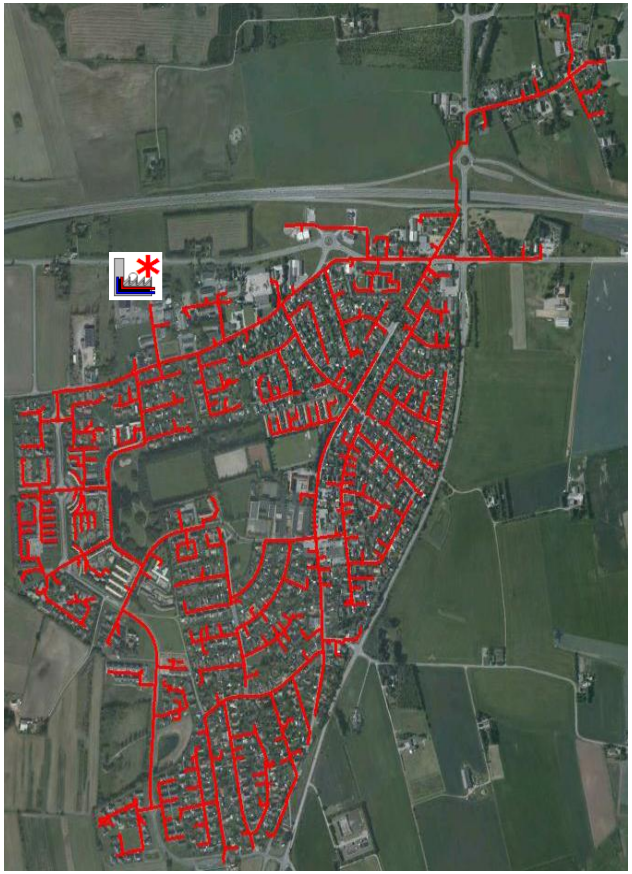
Real-Life District Heating Network

The model consists of 31,356 Km of main pipework trace. There are 1.441 consumers in the model.

Each node has a load applied, which is calculated as the sum of the entire consumer loads connected to that node.

There are 110 bypasses in the model. All bypasses are set on 65° C, and are assumed to have measuring tolerance on 2,5° C.

To ensure accurate and fast calculation the network has been reviewed to eliminate short pipes and to combine adjacent pipes with the same dimension



Harlev DHN which is used for simulation of its DHN in TERMIS

Next Steps

- Complete the simplified model in Matlab
- Applied model for a real-life network and validate the model
- Optimal supply temperature
- Temperature boosting as alternative solution for by-pass application

Thank You ☺

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