3rd International Conference on Smart Energy Systems and 4th Generation District Heating

Copenhagen, 12–13 September 2017

Quasi-dynamic simulation of district heating systems

funded by "Niedersächsische Vorab" 01/2016–12/2020

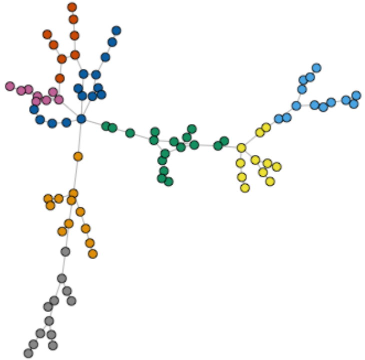
Johannes Pelda, M. Eng.

HAWK Faculty of Resource Management Göttingen

University of Applied Sciences and Arts Hildesheim/Holzminden/Göttingen

Copenhagen, 12 September 2017

Table of contents



Need for transformation of district heating systems (DHS)

1. Reduction of CO_2-emissions
2. Decreasing heat demand due to improved thermal insulation of buildings
3. Economic efficiency by enhanced operating efficiency
4. Linkage between different energy markets → more flexibility necessary

⋮

→ This demands transformation of district heating systems.

→ Simulation algorithms shall meet the needs of the transformation of 3^{rd} generation towards 4^{th} generation in a technical and economical perspective.

Objectives for an innovative simulation of district heating systems

What must be done to handle thermal and hydraulic limitations caused by reduced temperature difference between supply and return?

Where are the optimal locations in the system for technical actions to compensate hydraulic limitations?

When are different price models reasonable?

Who cannot cope lower supply temperatures?

Available commercial software

- termis
- sysHYD
- OptiPlan
- ROKA
- STANET

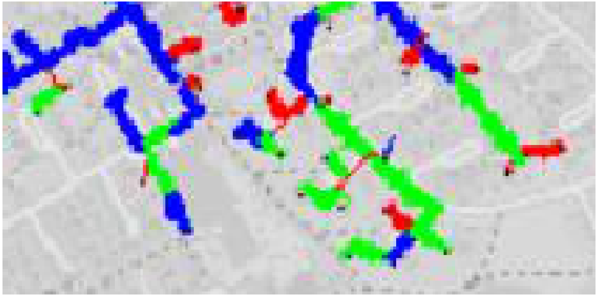


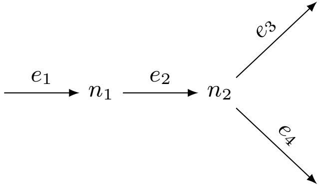
Figure Map of heating system by STANET

Quasi-dynamic simulation

Main focus: Several tools helping to transfer DHS into DHS of 4$^{\text{th}}$ generation

- Open-source
- Utilisation of Qgis and gis-tools
- Public documentation
- Technical flexibility
- Environmental impact
- Package for python
- Calculation of DHS over a time period

The graph theory helps to formulate all balances that are needed for calculation of the district heating system.
The graph theory defines a incidence matrix as the following example shows:



$$\underline{I} = \begin{matrix} & e_1 & e_2 & e_3 & e_4 \\ n_1 & 1 & -1 & 0 & 0 \\ n_2 & 0 & 1 & -1 & -1 \end{matrix} \tag{1}$$

$$\vec{\dot{m}} = \begin{pmatrix} \dot{m}_{e1} \\ \dot{m}_{e2} \\ \dot{m}_{e3} \\ \dot{m}_{e4} \end{pmatrix} \tag{2}$$

mass balance

$$\underline{I} \cdot \vec{\dot{m}} = 0 \tag{3}$$

$$\begin{pmatrix} \dot{m}_{e1} - \dot{m}_{e2} \\ \dot{m}_{e2} - \dot{m}_{e3} - \dot{m}_{e4} \end{pmatrix} = 0$$

Additionally, other balances and constraints determine finally the equation system:

- energy balances
- impulse balances
- mass dependencies
- thermal dependencies
- pressure dependencies

→ State of the art to calculate directed graphs (Bose et al., 1996; König, 1936).

→ The equation system can be solved by a solver of the Python module `scipy`.

Hydraulic load factor (HLF)

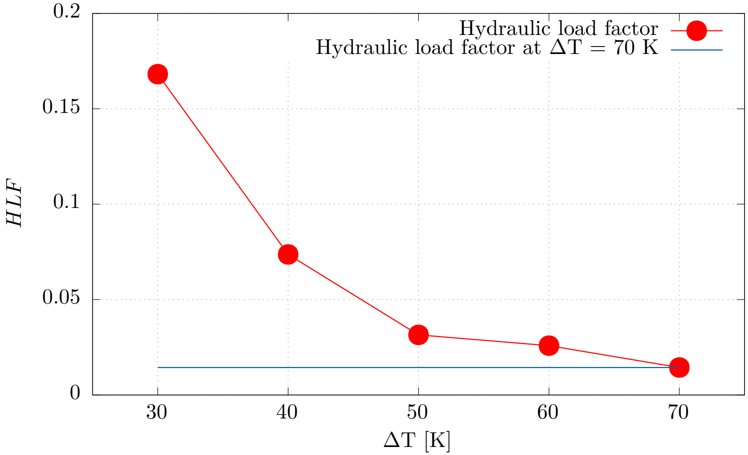
$$HLF = \frac{\text{length of pipes with } VUR \geq 1}{\text{DHS's total pipe length}} \tag{4}$$

$$VUR^1 = \frac{\dot{V}_{operation}}{\dot{V}_{max}} \tag{5}$$

→ HLF as benchmark helps to identify hydraulic limitations.

→ Technical options for influencing HLF are analysed.

[1] **v**olumetric **u**tilisation **r**atio of pipe



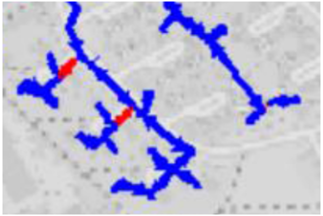


Figure $\Delta T = 70K$

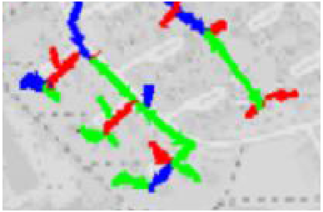


Figure $\Delta T = 30K$

Next development steps

Limitations of HLF:

- HLF does not weight bottlenecks with technical and economic parameters.
- HLF does not qualify bottlenecks in terms of relevance.

Further research approach:

→ Weighting of bottlenecks with technical and economic parameters

→ Best location for decentralised heat sources and storages (e.g. Power-to-heat, renewable heat sources as well as integration of low-grade waste heat)

→ Demand side management

→ Increase of pipe's nominal diameter

Summary

- Future market challenges demand a transition of DHS towards 4^{th} generation.
- QuaDNeSim promises to answer technical questions arising due to this transformation.
- Optimisation algorithms can face challenges of big data.

Thank you for your attention!

Johannes Pelda, M. Eng.
– Research Associate –

johannes.pelda@hawk-hhg.de
+49 / 551 / 5032 - 185

University of Applied Sciences and Arts Hildesheim/Holzminden/Göttingen
Faculty of Resource Management – working group NEUTec –
Rudolf-Diesel-Straße 12
37075 Göttingen
Germany

Bose, Nirmal K. and Ping Liang (1996). *Neural network fundamentals with graphs, algorithms and applications.* McGraw-Hill series in electrical and computer engineering. Communication and signal processing. New York: McGraw-Hill. ISBN: 9780070066182.

König, Dénes (1936). *Theorie der endlichen und unendlichen Graphen: Kombinatorische Topologie der Streckenkomplexe.* Ed. by Akademische Verlagsgesellschaft m. b. h. Leipzig. (Visited on 09/06/2017).