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Gas Quality Tracking in distribution grids with SmartSim – a new kernel for flow calculation

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FACULTY OF MECHANICAL ENGINEERING
Chair of Thermodynamics

e·on

SmartSim at a Glance

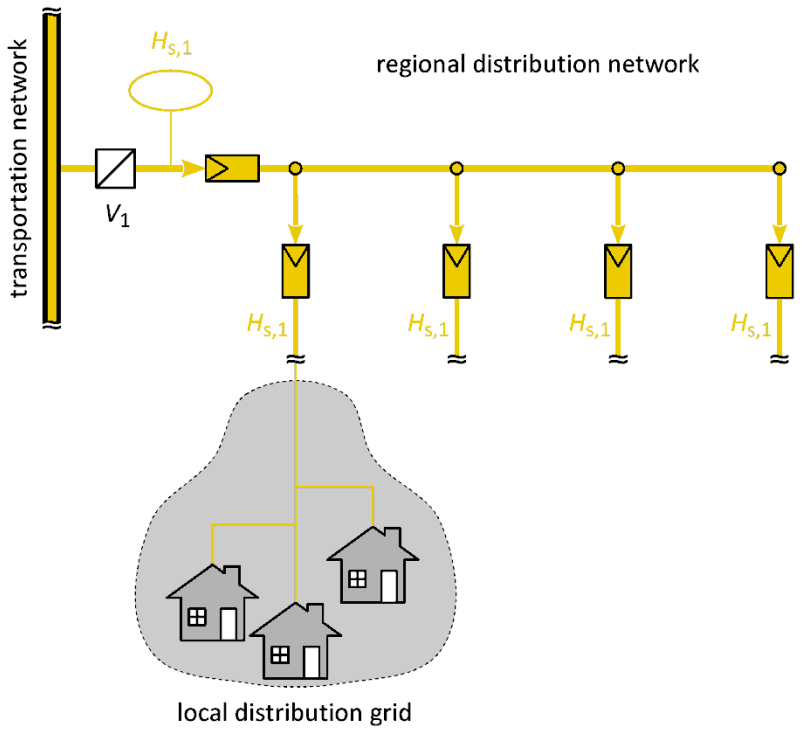
- motivation
  - European gas market growing together
  - rising LNG imports
  - increasing production of biomethane

- goals
  - develop a method for gas quality tracking in distribution grids
  - enable billing for multi-point injection of different gases (e.g. natural gases, biomethane, hydrogen)
  - obtain approval in legal metrology
  - avoid admixture of propane in case of biomethane injection

Lower costs & greener gas
SmartSim concept reflects the idea of an intelligent distribution grid

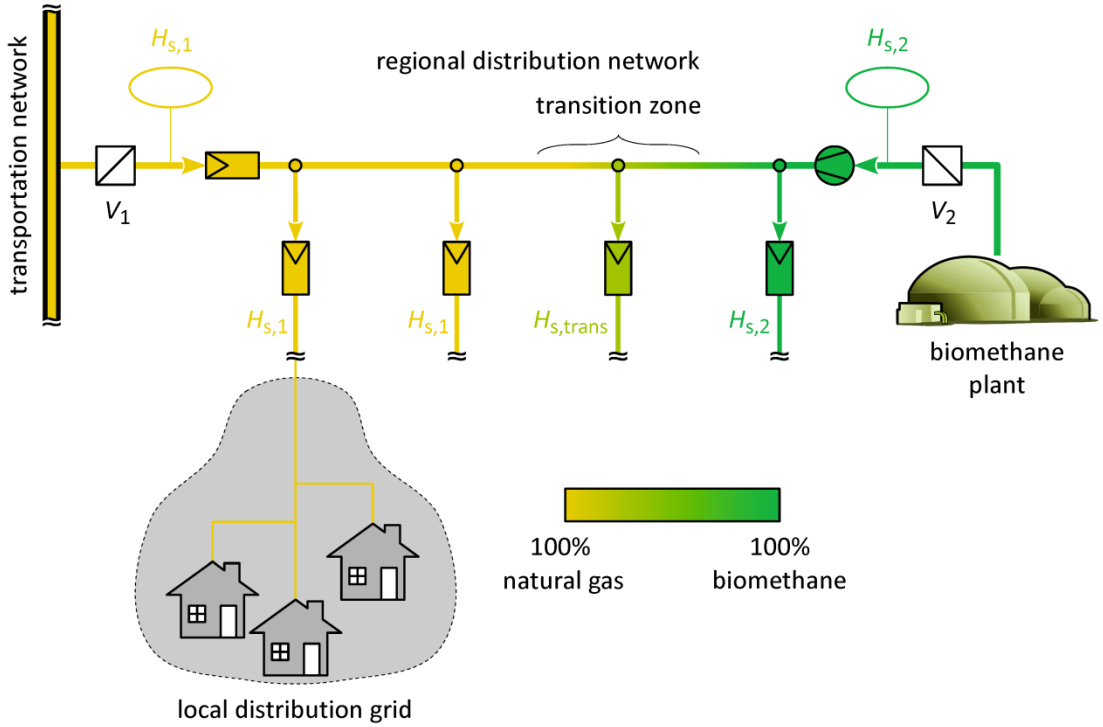
Single- vs. Multi-Point Injection

- billing in accordance with legal metrology
- single-point injection
  - billing on the basis of one volume-weighted CV for all exit points



Single- vs. Multi-Point Injection

- billing in accordance with legal metrology
- multi-point injection
  - billing on the basis of a single volume-weighted CV for the entire grid only admissible if 2 % limit is observed

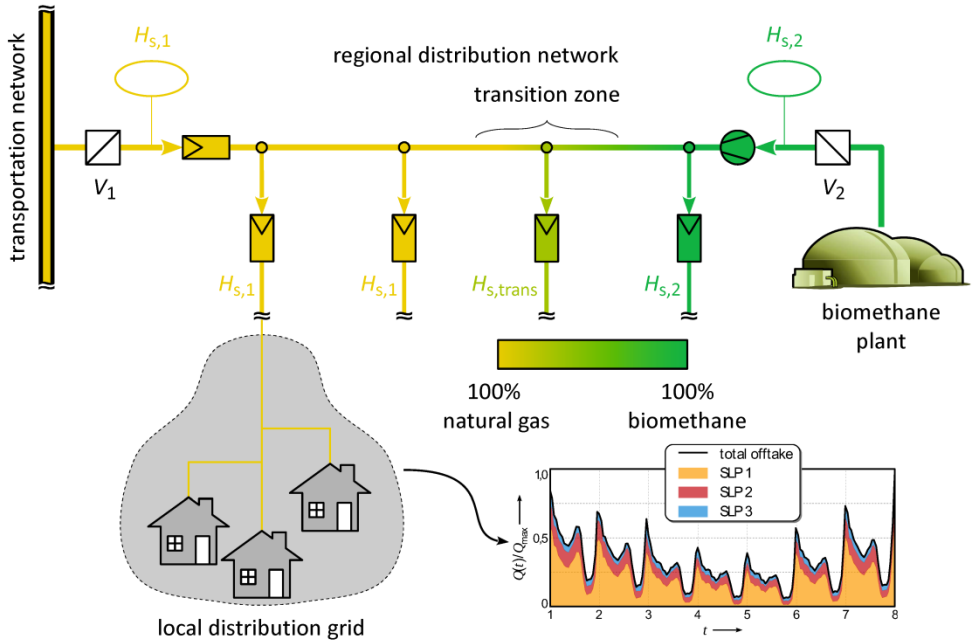


Multi-Point Injection | Challenge of Biomethane

- compliance with 2 % limit only possible if CV is adjusted, e.g. conditioning of biomethane by admixing propane
- remedial measure: calculate CV if 2 % limit is exceeded
  - allocate CVs on the basis of state of flow estimation through the grid

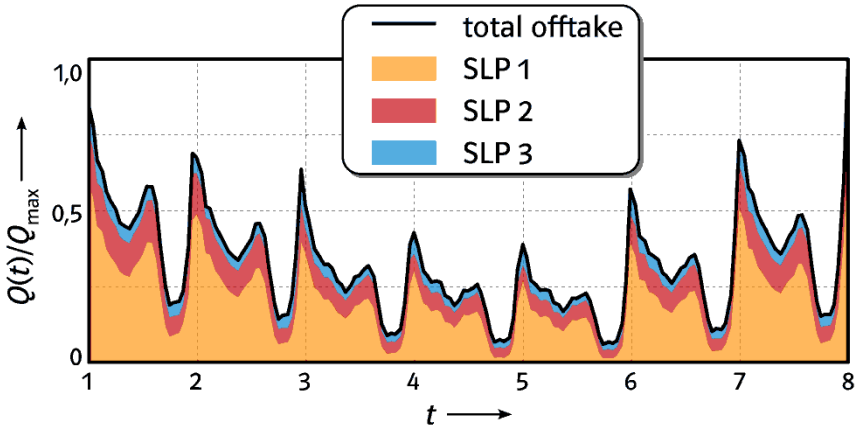
- but: volume flows at exit points are not known

- therefore: calculate volume flows at exit points

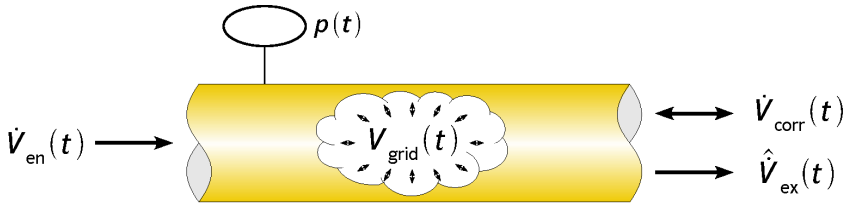


SmartSim Approach | Volume Calculation

1. volume at exit points
   estimate volumes on the basis of standard load profiles (SLP) including temperature and customer specific consumption data



2. correction of volumes
   correction method on the basis of a volume balance including pressure information (line pack)

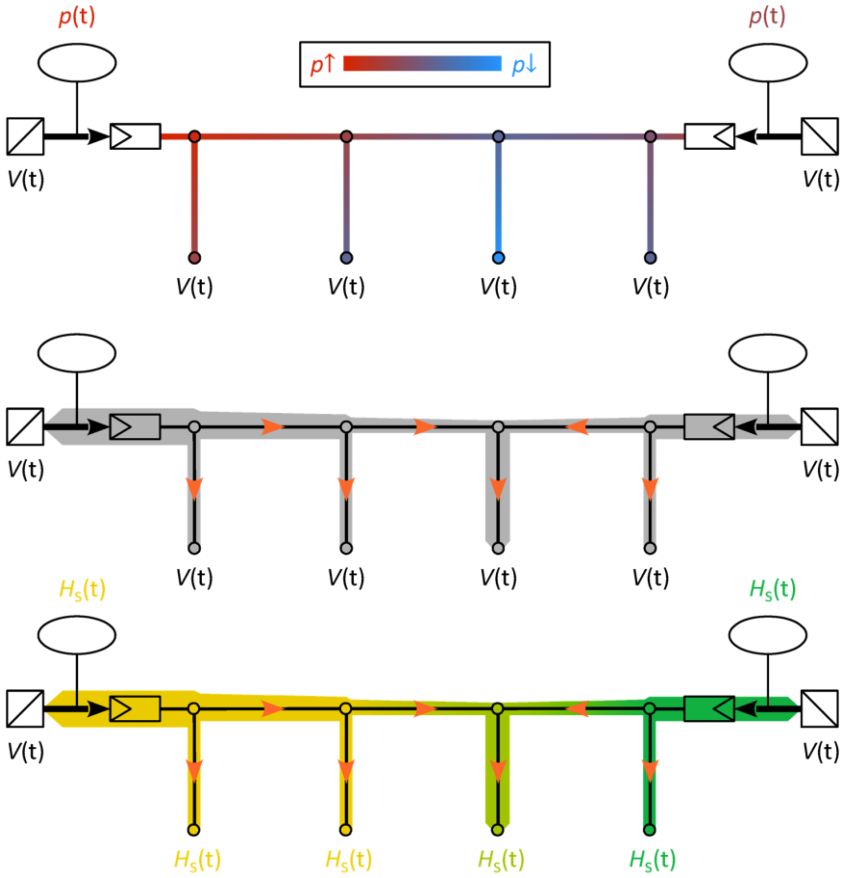


SmartSim Approach | Hydraulic Simulation

- development of a novel quasi-stationary kernel for state of flow simulation in gas distribution grids with focus on accuracy and computation time

iteration step

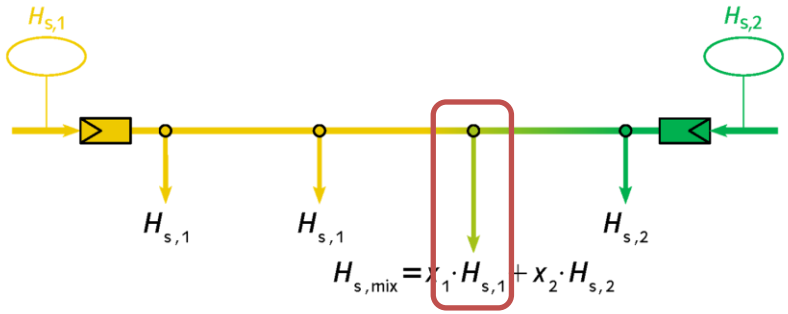
- pressure distribution with respect to actual density (real gas behaviour uses e.g. SGERG)
- calculation of flow velocities and volume flows (mass conservation)
- determination of gas quality with integrated package model



SmartSim Approach | Back Propagation

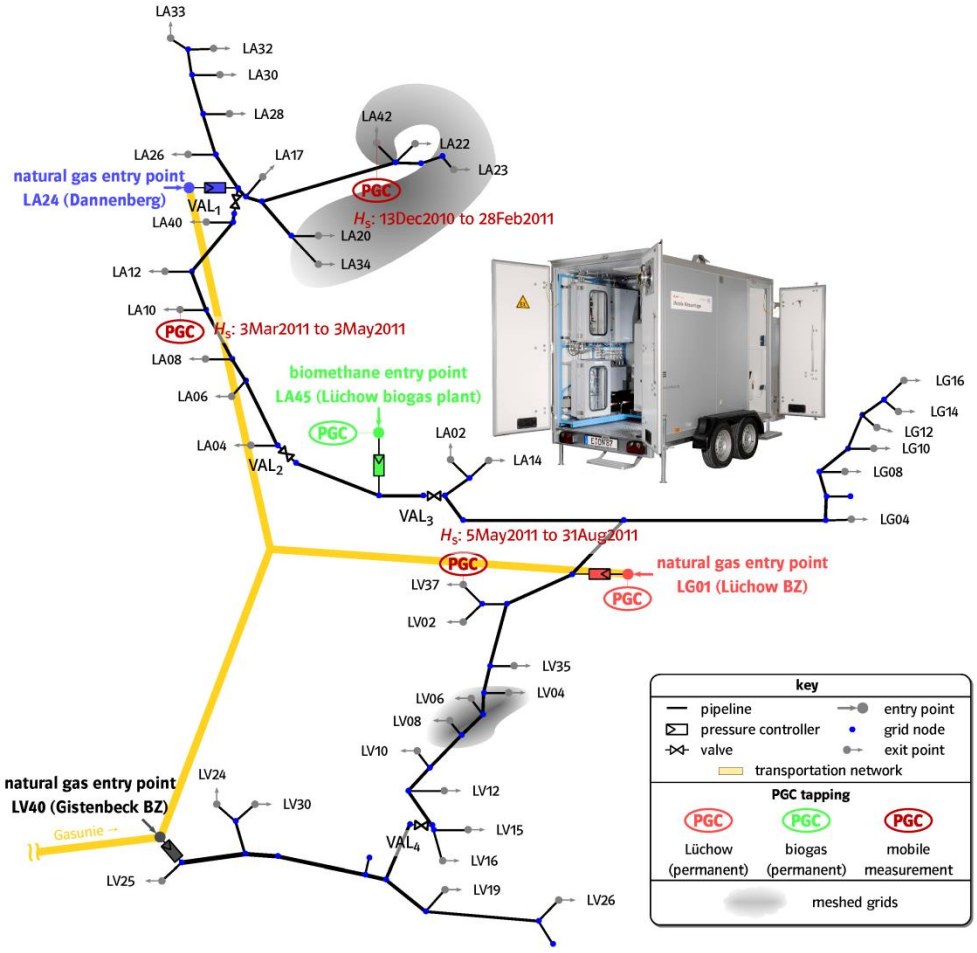
- determination of CVs at exit points and tracing CVs back to entry points

- advantages
  - any exit value can always be assigned to verified entry values
  - other relevant gas characteristics can be derived in single calculation step (e.g. *K* number or CO_2 emission factor)



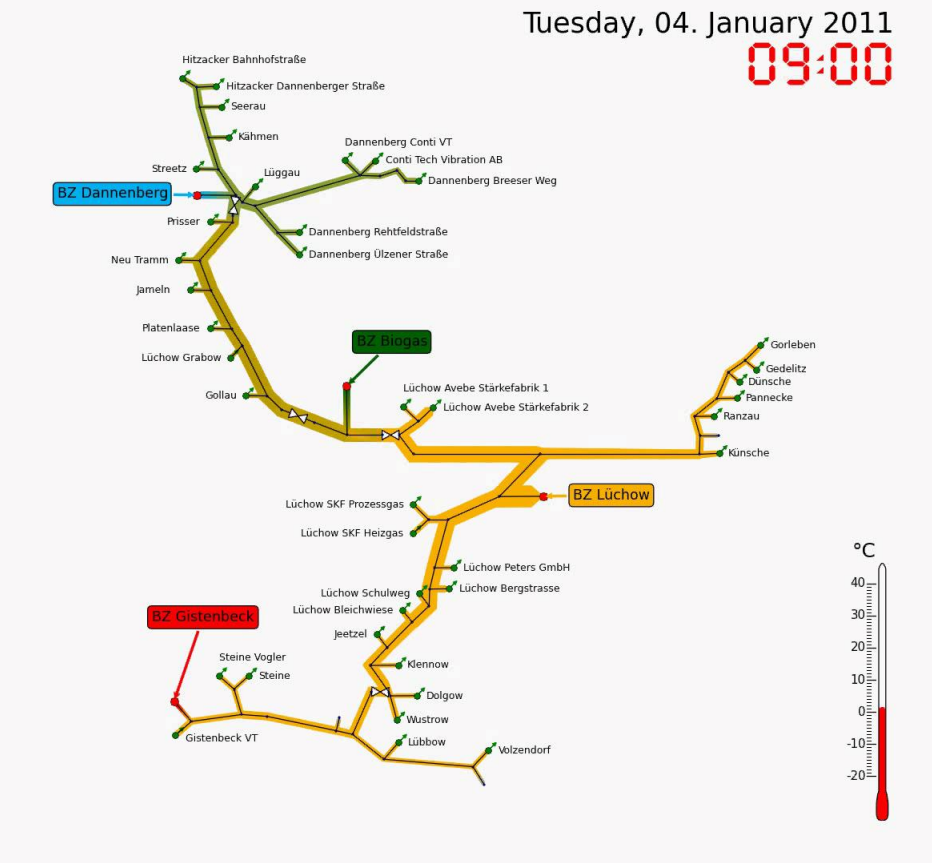
Validation of New Simulation Kernel

- gas distribution grid “Lüchow” operated by Avacon used for validation
- grid data
  - 80 km pipe length
  - 3 natural gas entry points
  - 1 biomethane entry point
  - 40 exit points
- validation
  - comparative measurements using mobile PGC in 9 month field test
  - further comparison with reference software



SmartSim State of Flow Showcase

- typical flow situation shows high demands during winter season



Field Test Results

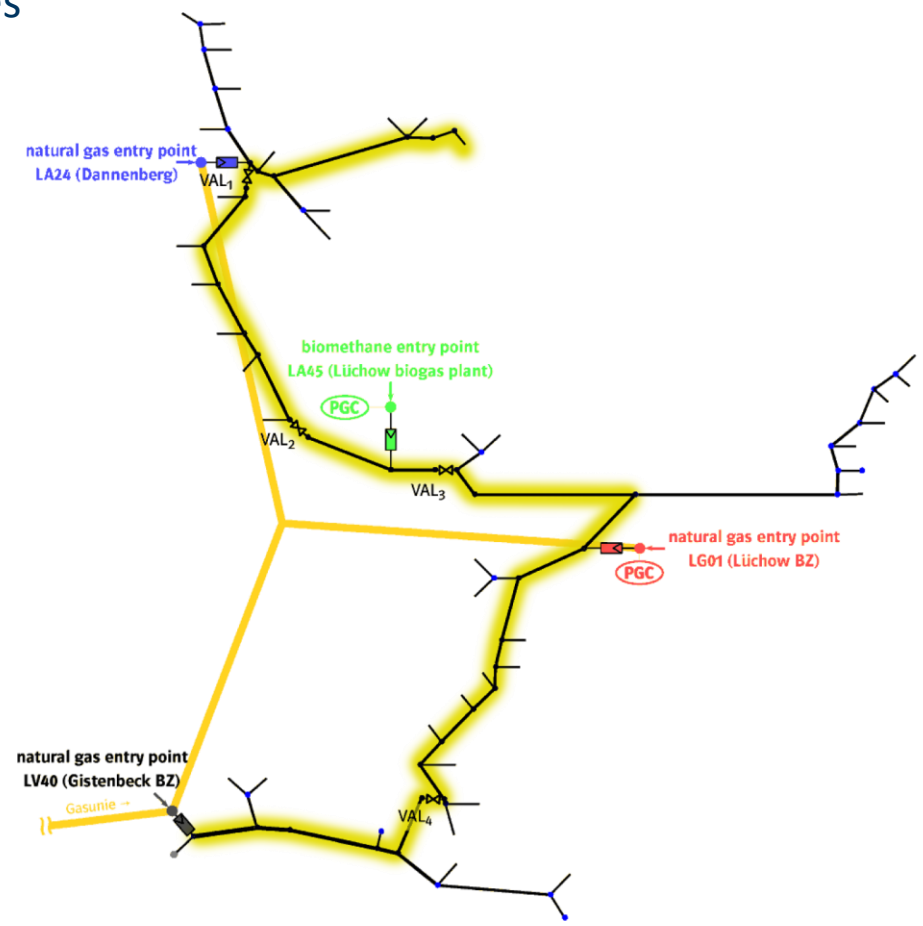
- determination of volume-weighted monthly average CV
- field test duration from 01.12.2010 till 01.09.2011

Month	SmartSim
	CV_{new} kWh/m³
12.2010	11.368
01.2011	11.334
02.2011	11.338
03.2011	11.275
04.2011	11.273
05.2011	11.353
06.2011	11.355
07.2011	11.308
08.2011	11.211

- deviation always < ± 0.1 % between calculated and measured CVs
- no significant deviation from reference software

Comparison with Reference Software

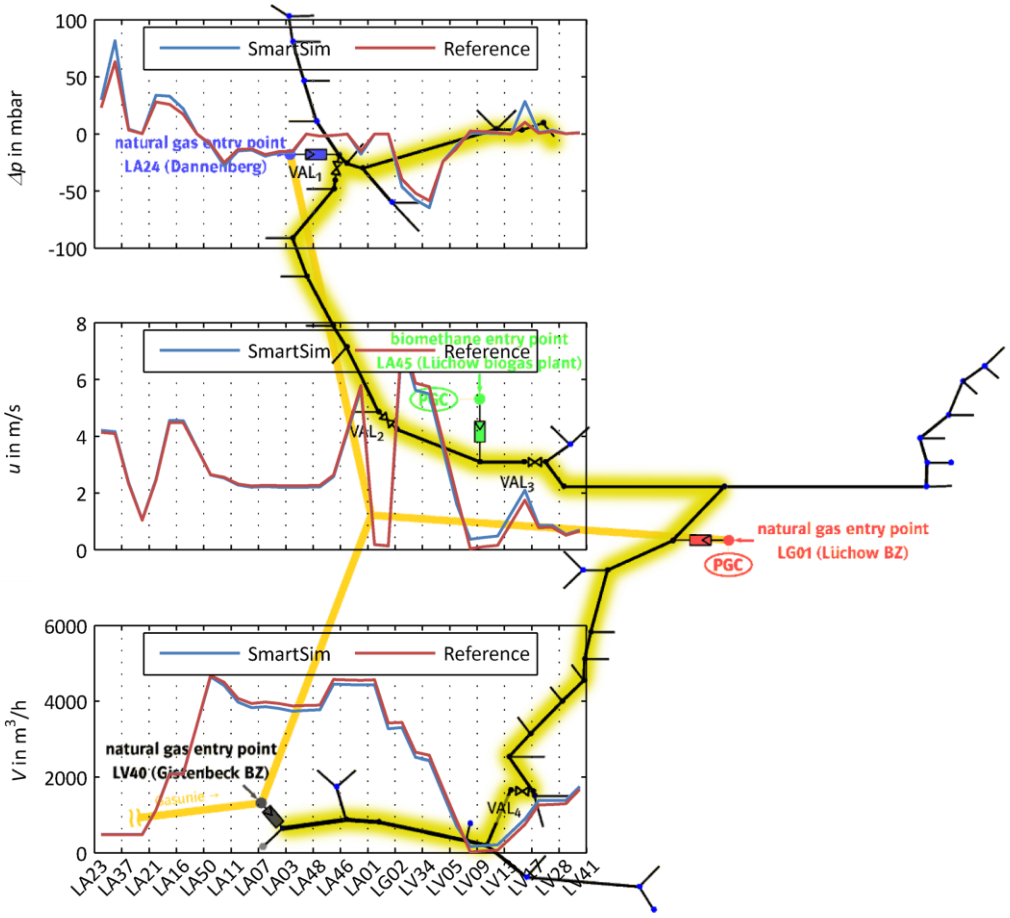
- comparison between new kernel and reference software performed on hourly basis
- compared state of flow properties
  - pressure
  - flow velocities
  - volume flow
- shown along main path with highest pressure loss (highlighted yellow)

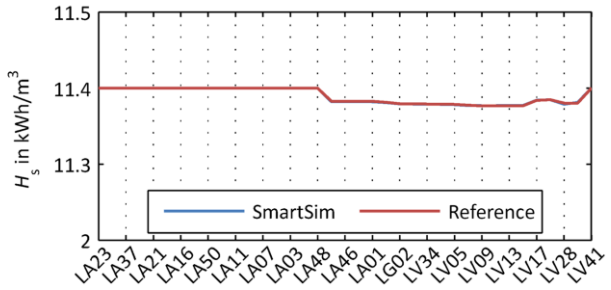


Comparison with Reference Software

- selected time point with highest pressure loss (03.03.2011 07:00)
- typical deviation are shown
- CV distribution depends on state of flow properties

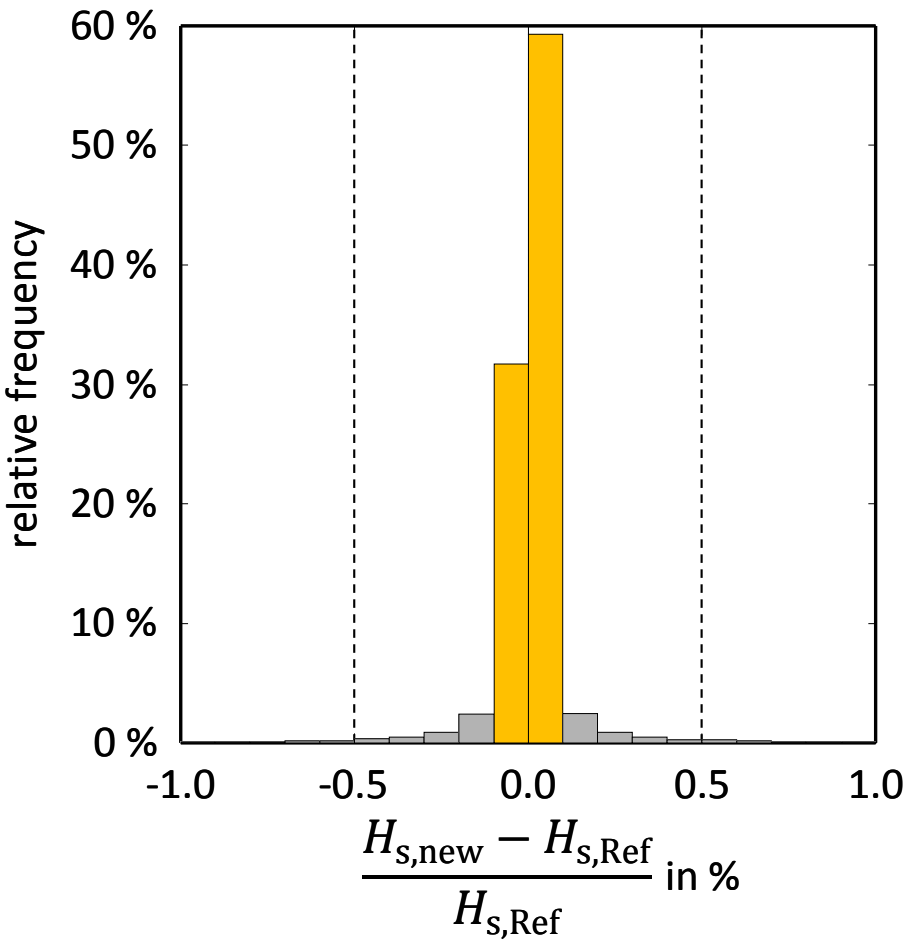
- evaluation of CV deviation comprises time period from 01.12.2010 to 01.10.2011 (about 670,000 data points)





Comparison with Reference Software

- selected time point with highest pressure loss (03.03.2011 07:00)
- typical deviation are shown
- CV distribution depends on state of flow properties
- evaluation of CV deviation comprises time period from 01.12.2010 to 01.10.2011 (about 670,000 data points)
- 91 % of all deviations < ± 0.1 %
- indicating minimal deviations between SmartSim and reference software



Uncertainty Calculation by Monte Carlo Simulation

- derive resulting uncertainty from input variable uncertainty
  - method according to “Guide to the Expression of Uncertainty in Measurement”
- method well-suited for complex tasks e.g. gas distribution grids

- assumed input uncertainty (lower and upper boundary)

input variable	uncertainty limit
pipe roughness	[20 % … 200 %]
pipe diameter	[85 % … 115 %]
pipe length	[94 % … 106 %]
SLP energy	[70 % … 130%]
measured offtake	[97 % … 103 %]
entry volume	[97 % … 103 %]
entry pressure	[94 % … 106 %]
gas temperature	[98.2 % … 101.8 %]

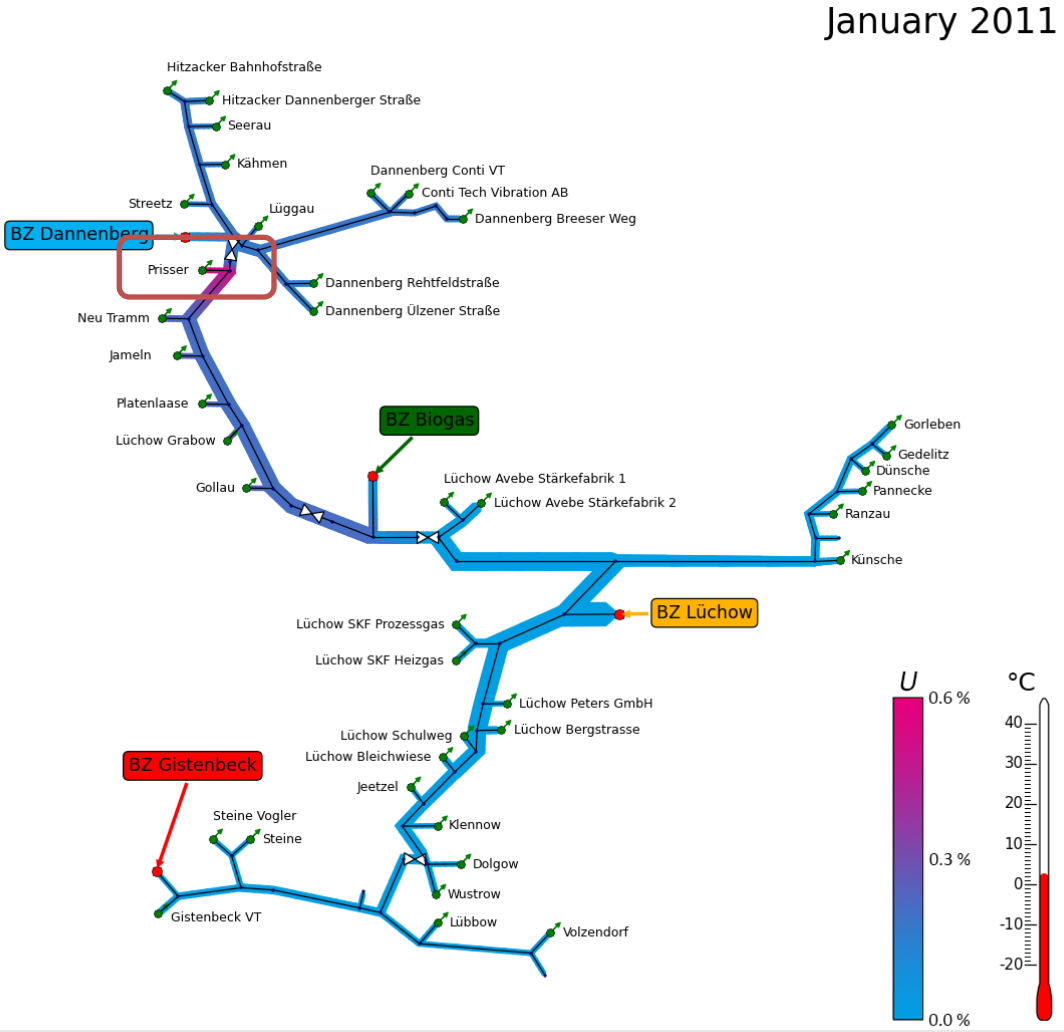
Monte Carlo Simulation | Visualisation of Results

- January 2011 illustrates high volume flows during winter season
- average state of flow presented

January 2011

Monte Carlo Simulation | Visualisation of Results

- January 2011 illustrates high volume flows during winter season
- uncertainty distribution visualised
- resulting uncertainty $U < 0.6\ \%$
- input CVs adapted to simulate unconditioned biomethane
- Monte Carlo Simulation used to identify and quantify sections high uncertainties
- billing approval by German authorities granted in August 2012



Conclusion and Outlook

- novel calculation kernel developed
  - high level of accuracy and extremely short computation times
  - excellent agreement with reference software
  - small deviation to measured CVs
  - results can be transferred to more complex and intermeshed grids

- uncertainty calculation in gas distribution grids
  - performed for the first time
  - in accordance with GUM
  - expanded uncertainties below 2 % limit despite of conservative input uncertainties

- calculation kernel will be implemented for transmission grids