Contingency Analysis for Gas Networks with H_2 Injection

Math Energy

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Bundesministerium für Wirtschaft und Energie

Fraunhofer SCAI

Contingency Analysis for Gas Networks with H_2 Injection

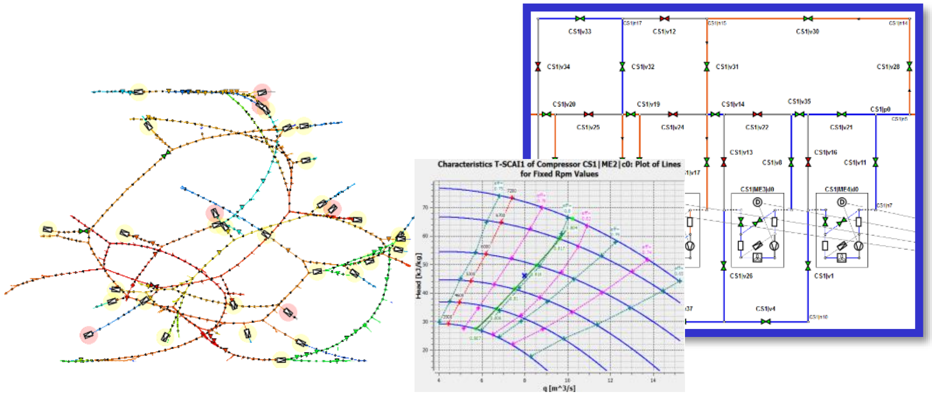
MYNTS

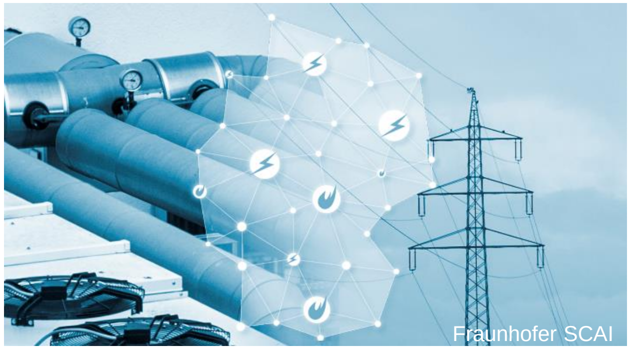
<u>Tanja Clees</u>, Anton Baldin, Kläre Cassirer, Bernhard Klaaßen, Lialia Nikitina, Igor Nikitin, Sabine Pott, I. Torgovitskaia et al.

Fraunhofer SCAI

53757 Sankt Augustin, Germany

tanja.clees@scai.fraunhofer.de





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Motivation

- Contingency analysis is already common practice for power networks.
- At least, an ***N-1*** analysis for the most important components is performed.
  - For a network with ***N*** decisive components (power plants etc.), perform ***N*** simulations by cutting off one of these components at a time.
- However, this is not true for gas networks yet.
- For a EU country, only a simulation-free, very restricted variant ("gas ***N-1*** standard of the EU Regulation"), necessary for assessing security of supply
  - "The N-1 formula is used to estimate whether the gas infrastructure of the country or area of study has enough technical capacity as to satisfy the total gas demand in the event of disruption of the single largest gas infrastructure during a day of exceptionally high gas demand occurring with a statistical probability of once in 20 years" [1].
  - [1] discusses usage of one hydraulic simulation of "the N-1 scenario".
- Here, we discuss and extend contingency analysis for gas networks.

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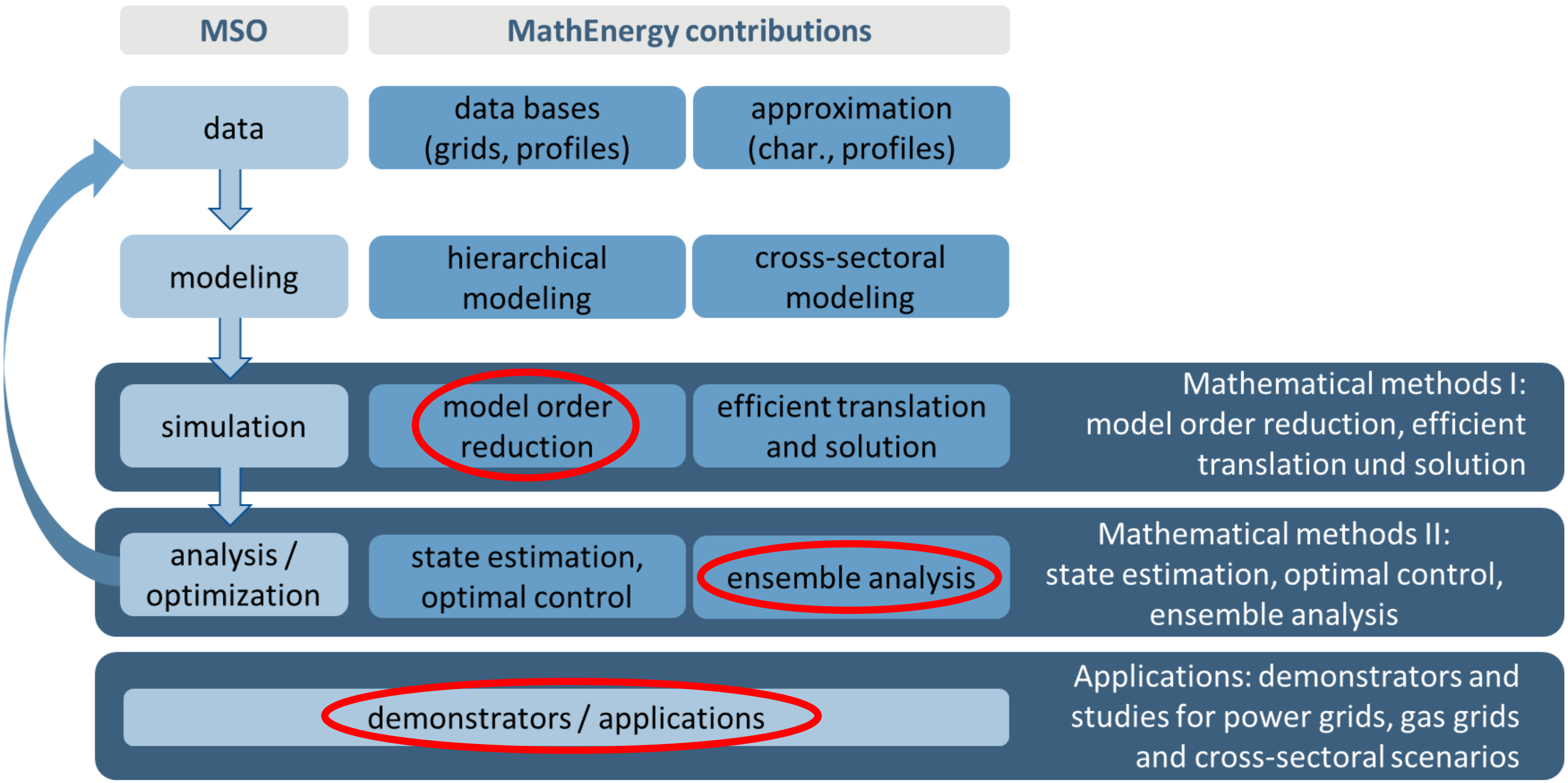
[1] Rodriguez-Gomez, N., Zaccarelli, N., Bolado-Lavin, R., Is the gas N-1 standard of the EU Regulation a good indicator of the security of gas supply of a country? Procs. Pipeline Technology Conf. 2018, Berlin

Key Aspects of this Contribution



Critical Infrastructure of a Gas Network

- Components of a (MYNTS simulation model of a pure) gas network:
  - nodes including
    - supply nodes with prescribed pressure or flow
    - demand nodes (including gas plants → sector coupling)
    - internal nodes
  - subnets and edges including
    - compressor stations (in the case of long-distance gas networks)
    - regulator stations
    - flaptraps
    - valves
    - Pipes
  - Most critical components are marked in red, additional ones in orange.

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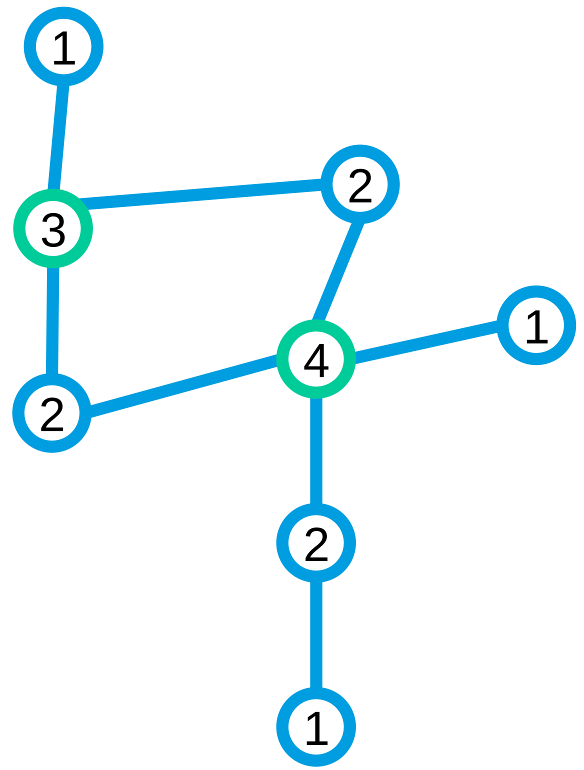
Key Idea – Introduction of Supernodes

- For each node, edges attached to it are counted.
- If the number is larger than a certain threshold (2 is used here), the respective node is called a supernode (in green):
- Supernodes are distributors or collectors.
- They (should) belong to the critical infrastructure as well.



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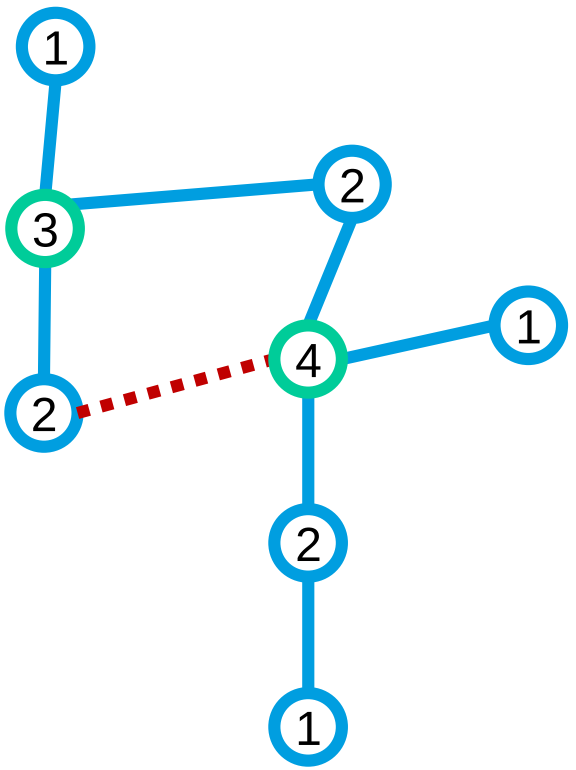
Integration of Supernodes into Contingency Analysis
→ CONT-1

- For each node, edges attached to it are counted.
- If the number is larger than a certain threshold (2 is used here), the respective node is called a supernode (in green):
- Supernodes are distributors or collectors and belong to the critical infrastructure.

- For integration into *N-1* analysis, two very different methods are possible:
  - Take out only one edge attached to a supernode at a time
  - Take out a whole supernode (all edges attached to a supernode)



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Integration of Supernodes into Contingency Analysis
→ CONT-S

- For each node, edges attached to it are counted.
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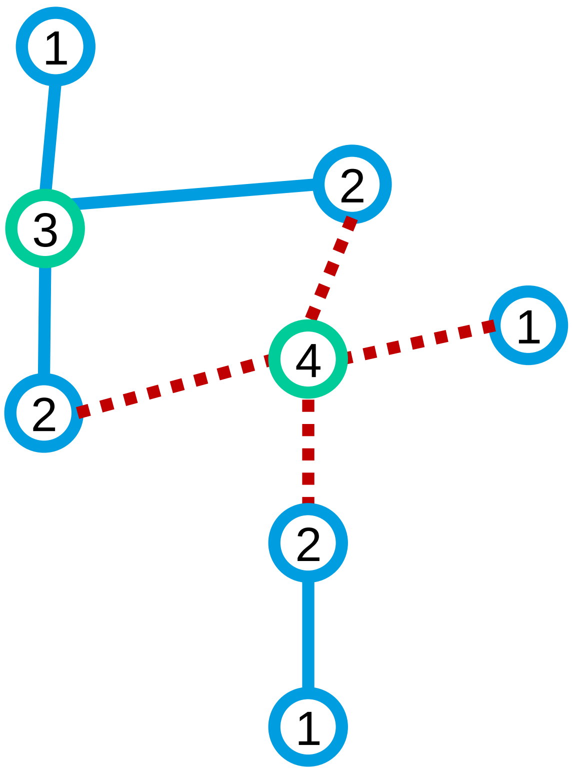

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Methods – Overview

1. TREERED - a novel method for topological reduction
   - It speeds up simulation runs and still allows for contingency analysis.
   - It preserves simulation results of the respective scenario (mass-conservative), but represents the scenario with fewer nodes and edges.
   - In particular, parts that serve for pure gas delivery purposes [i.e. without compressors, regulators, supplies (pressure, flow)], are collapsed.
2. Now, one of the novel methods for contingency analysis is applied:
   - CONT-C: classical *N-1* style; but besides compressor stations and important supply nodes, it also includes regulator stations, all pressure supply nodes, and important flow supply nodes
   - **CONT-1:** *in addition,* edges attached to supernodes are considered
   - **CONT-S:** *only* compressor stations and supernodes are considered

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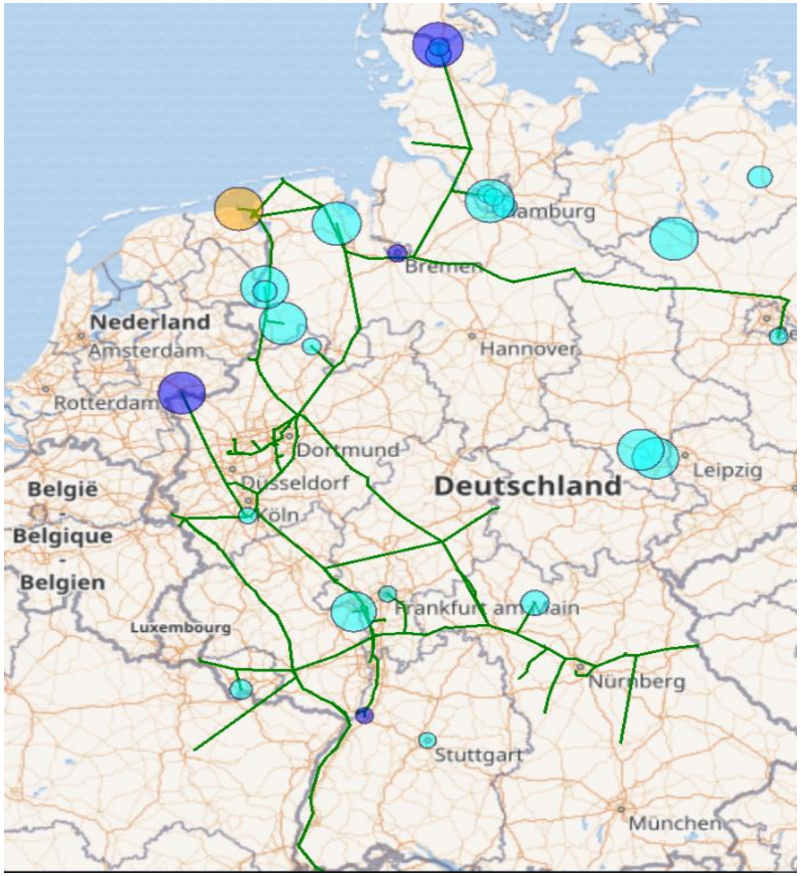
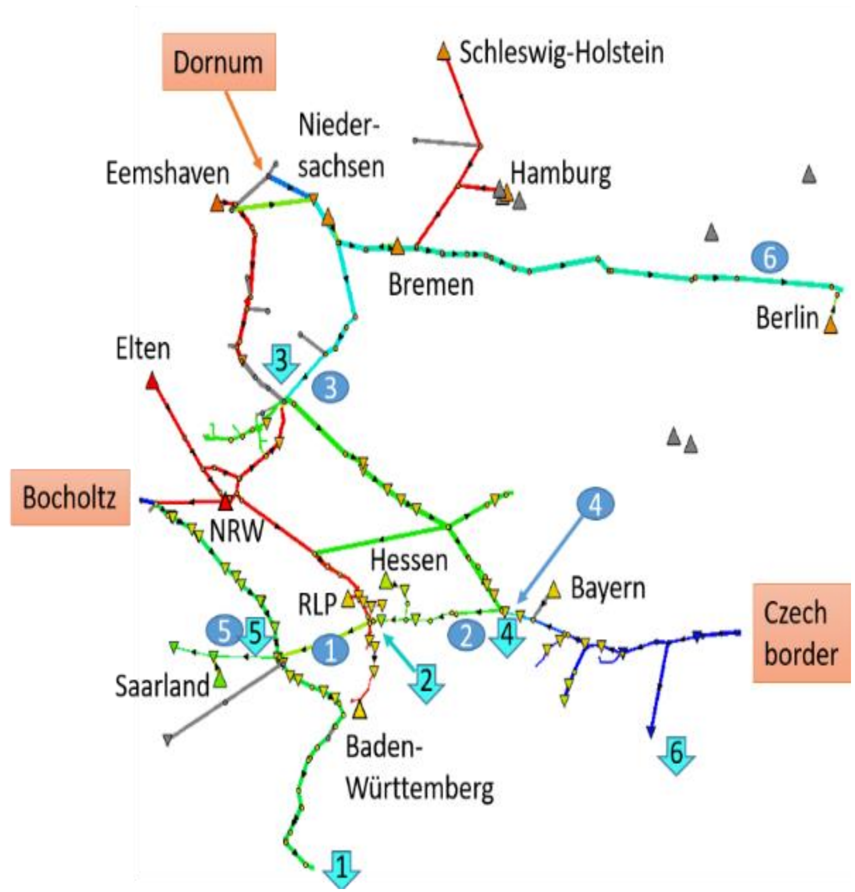
Exemplary Application – partDE-Hy Demonstrator





For more details on partDE-Hy, see separate video / slides.

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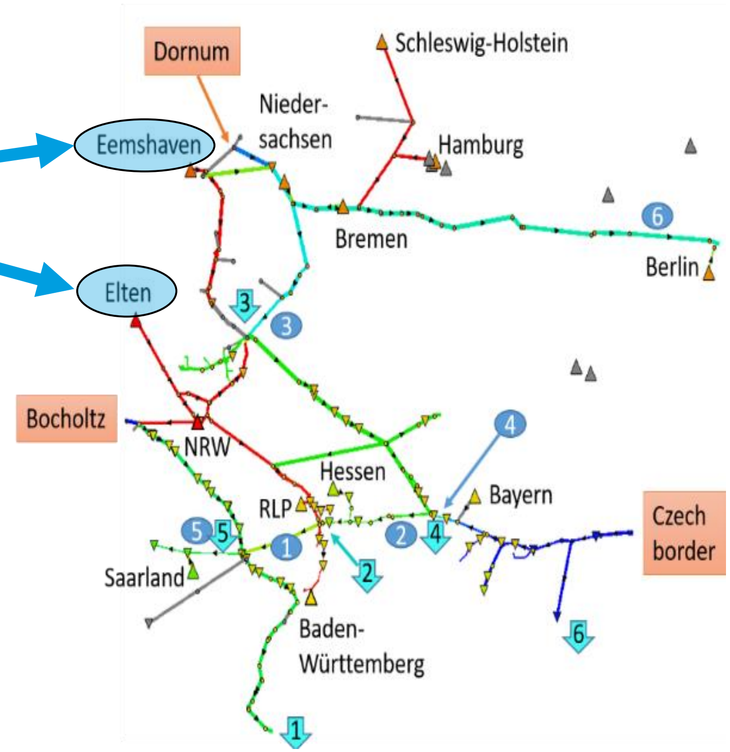
partDE-Hy Demonstrator – Scenarios Considered Here

- Base scenario (S-BA)
  - low to moderate injection mainly from two realistic locations (NL)
  - moderate case for contingency analysis
- Scenario with more hydrogen (S-HY)
  - moderate to high injection with a realistic magnitude and direction, mainly from North to South
  - a more challenging case due to larger amount of injection nodes and amounts.



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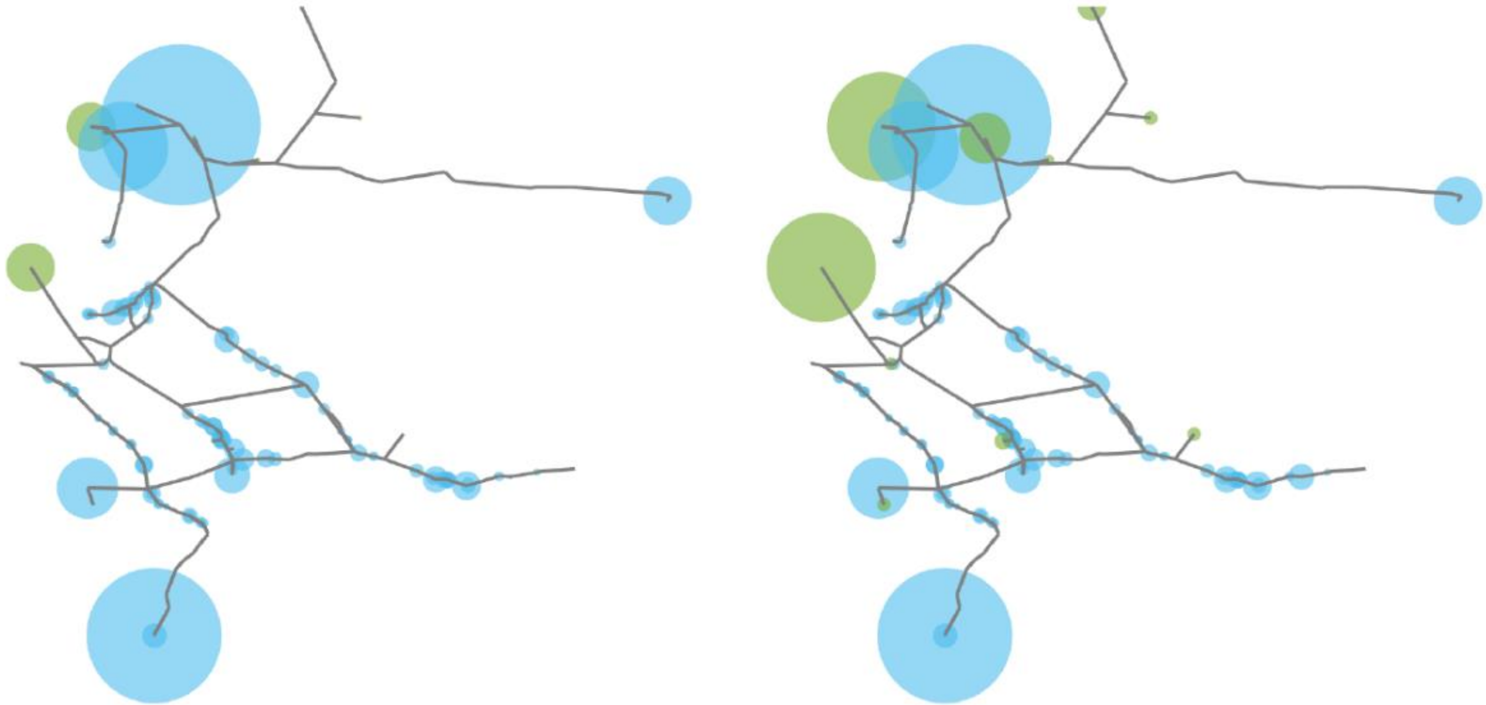
partDE-Hy Demonstrator – Scenarios Considered Here

- Location and magnitude of flow supplies (light green circles) and demands (light blue circles) for S-BA (left) and S-HY (right) on TREERED network:



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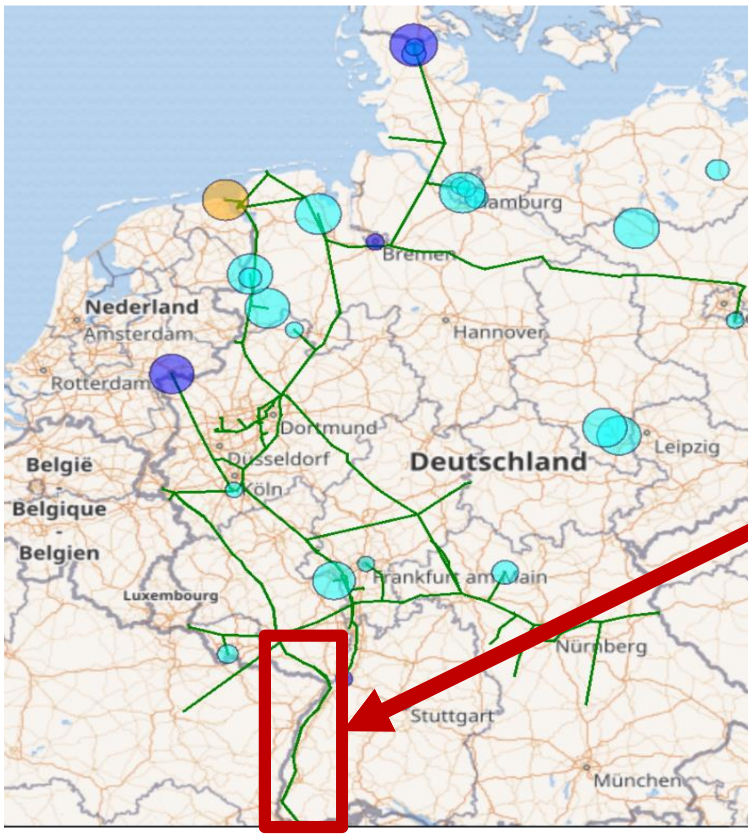
partDE-Hy – Special Attention to TENP

- TENP:



Starting in 2017 and planned to end in September 2020, capacity on the TENP I was reduced by a factor of around 50%.
This resulted from problematic network parts which were taken out of order consequently.
Problems were due to corrosion resulting from unsufficient, old coating. [2]

Supernodes provide a basis for a more detailed analysis.

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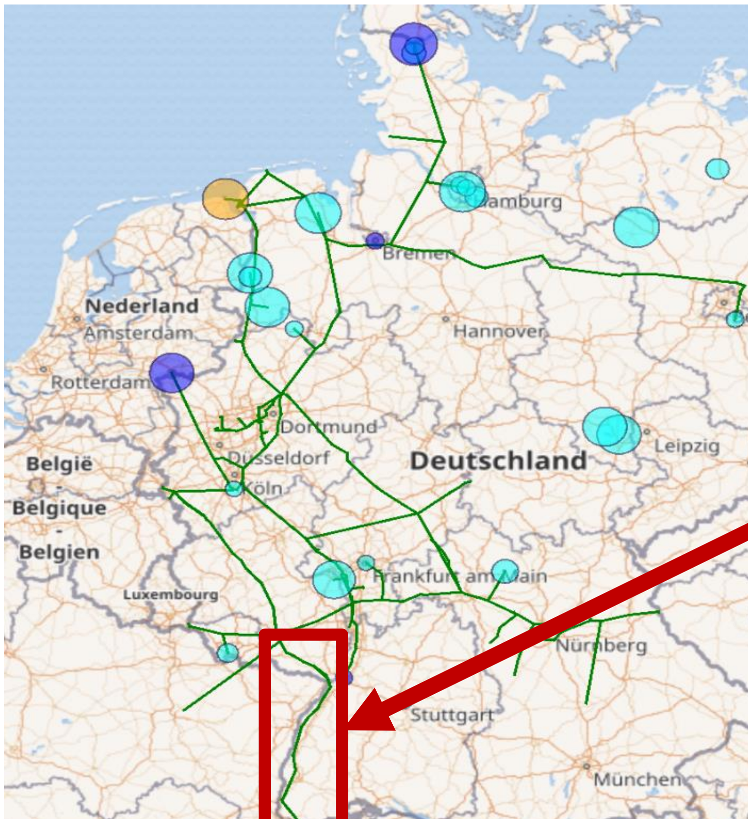
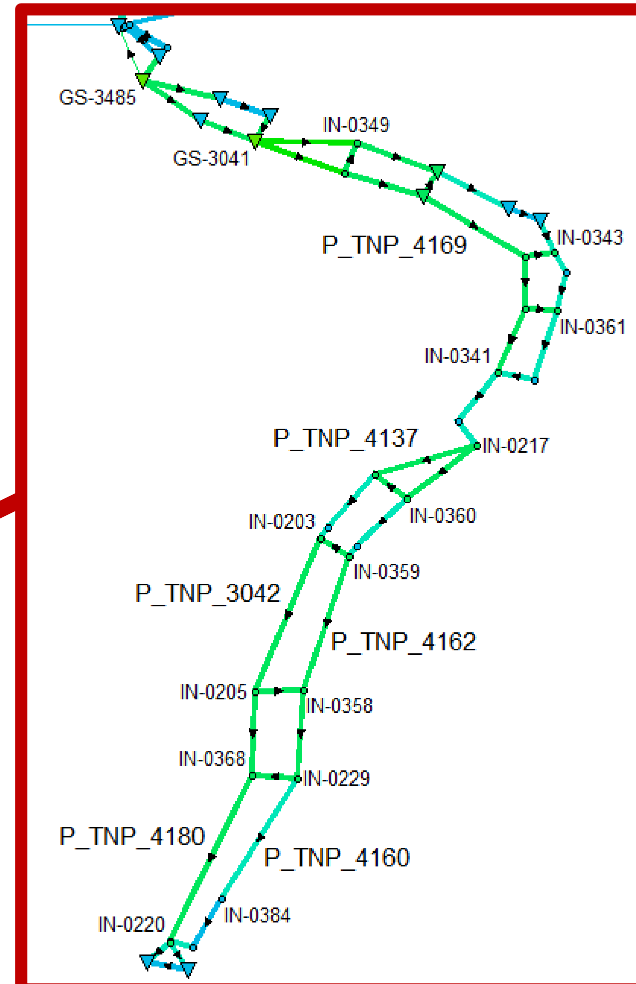
[2] https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/NetzentwicklungUndSmartGrid/Gas/NEP_2018/NEP_Gas_2018_Entwurf.pdf?__blob=publicationFile&v=4

partDE-Hy – Special Attention to TENP

- TENP:





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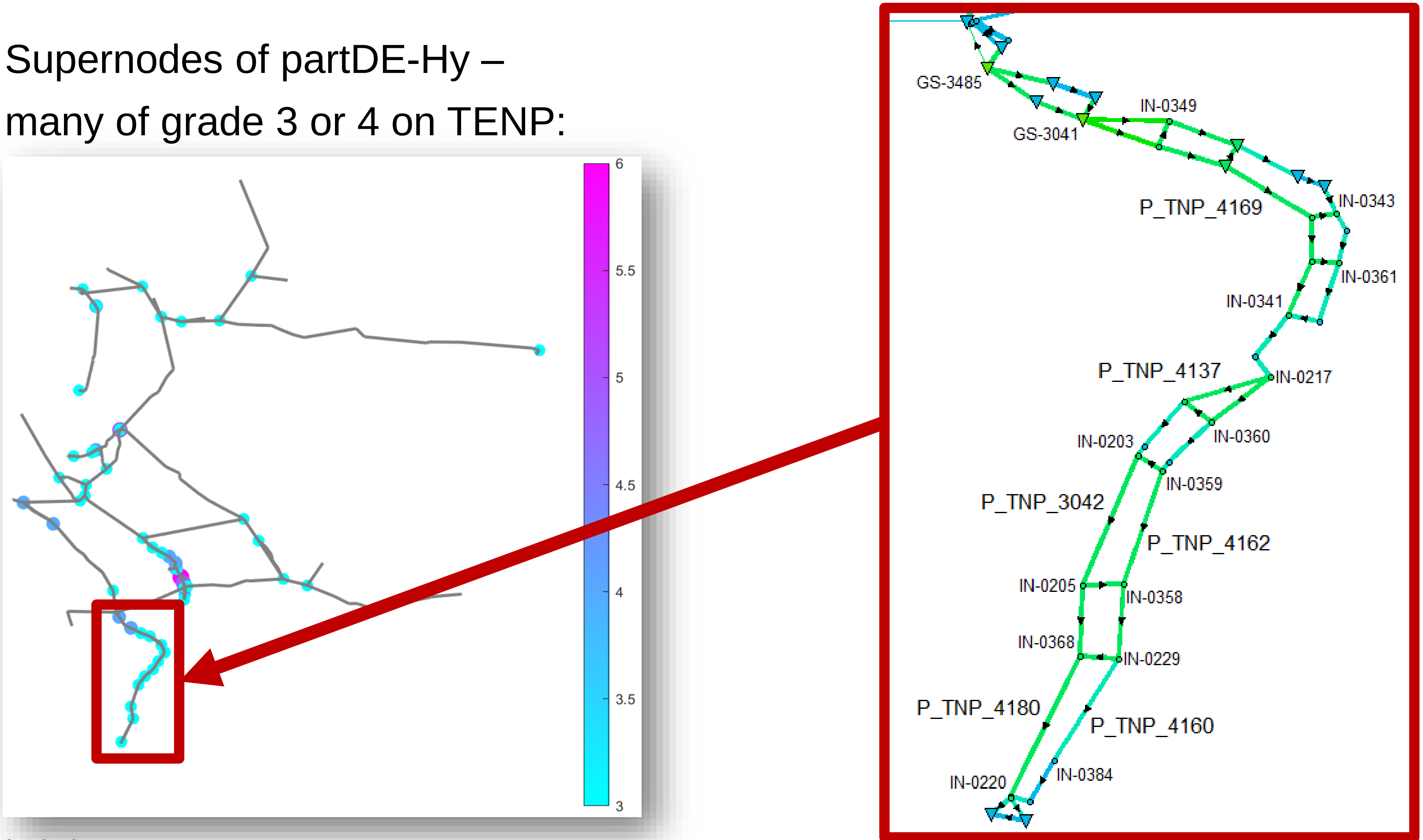
partDE-Hy – Special Attention to TENP

- Supernodes of partDE-Hy – many of grade 3 or 4 on TENP:



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Results for partDE-Hy – TREERED

- Number of elements* before and after application of TREERED

element type	original number	after TREERED	reduction to	reduction of
compressor stations	25	20	80%	20%
regulator stations	6	2	33%	67%
flaptraps	3	3	100%	0%
valves	208	16	8%	92%
pipes	431	297	69%	31%
inner nodes	342	164	48%	52%
flow supplies	20	10	50%	50%
pressure supplies	3	3	100%	0%
demand nodes	166	117	70%	30%

*) Each compressor station includes regulators, coolers, resistors, and valves; each regulator station includes a heater, resistors, and valves. Then, “valves" are those outside these stations.

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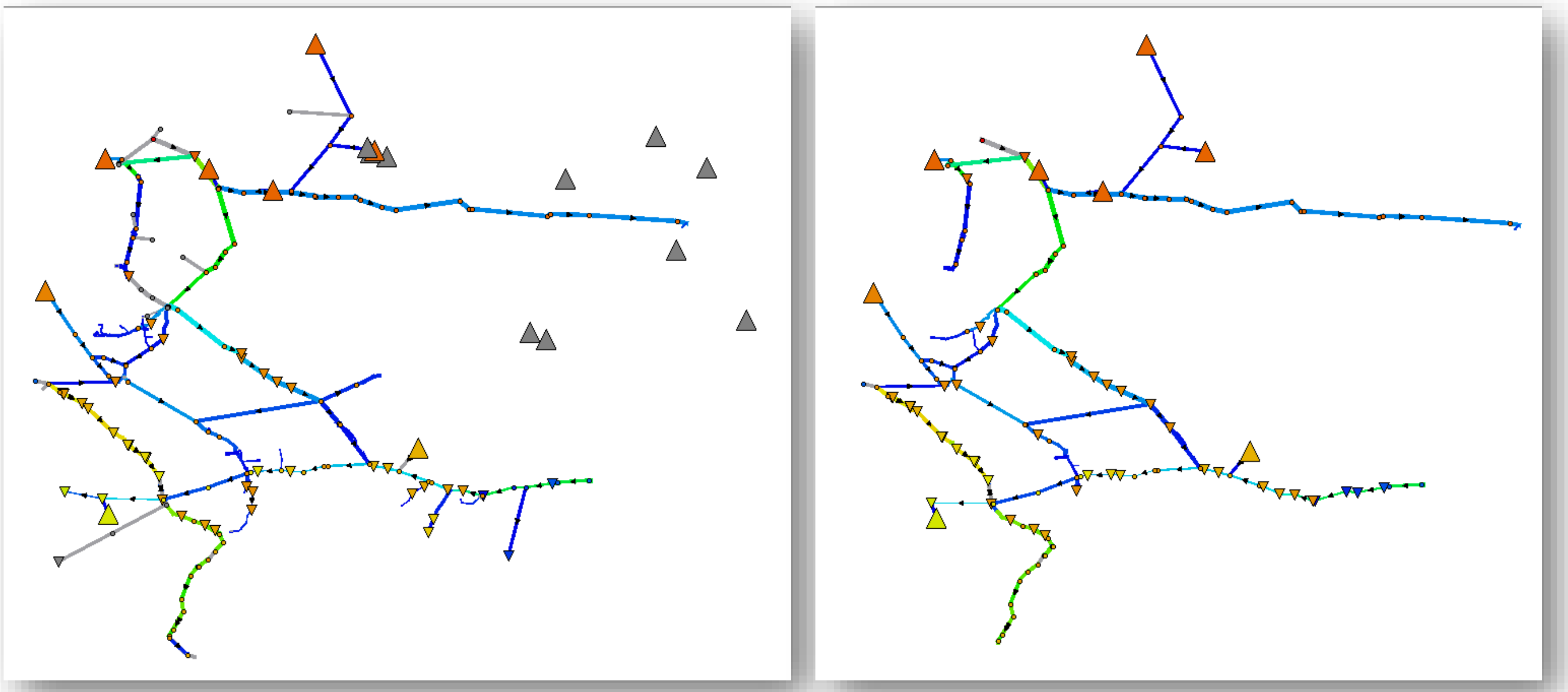
Results for partDE-Hy – TREERED

- Before (left) and after (right) application of TREERED



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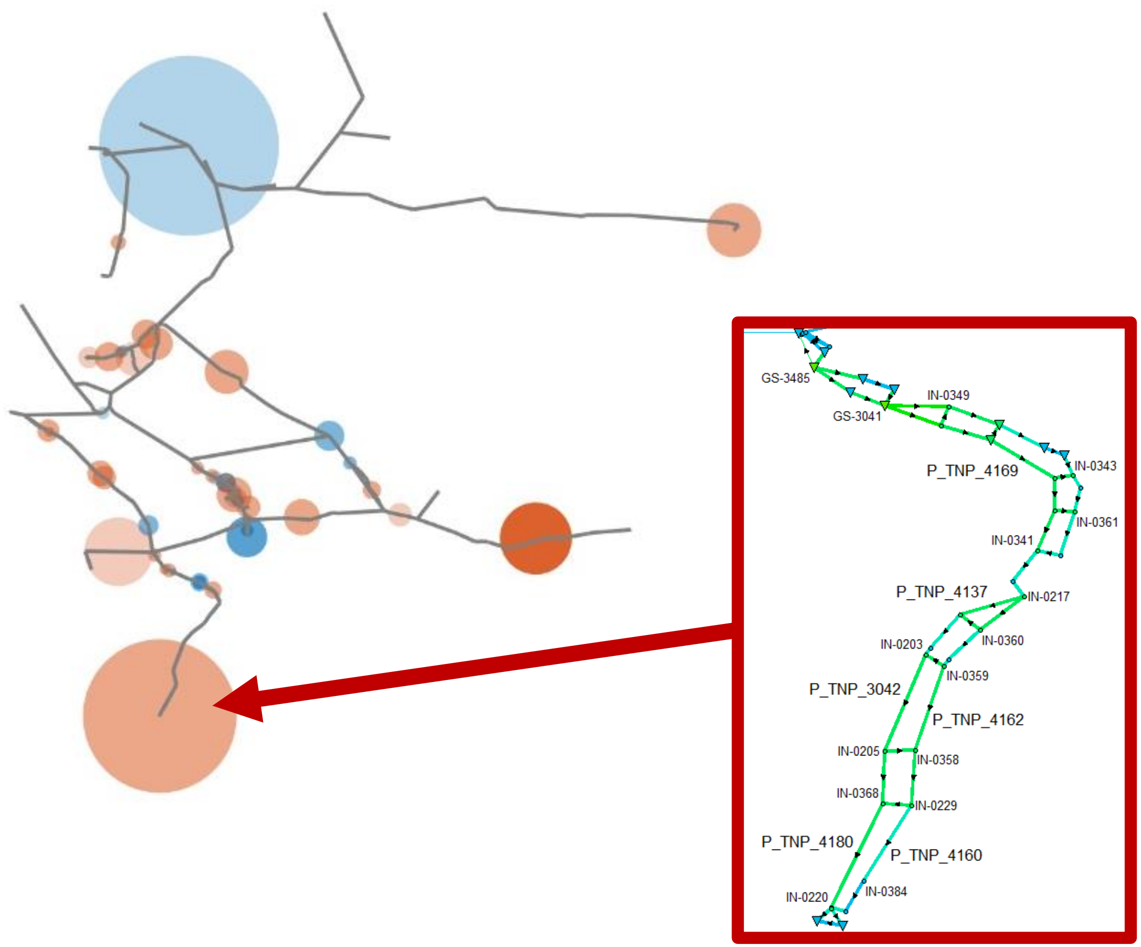
Results for partDE-Hy – Exemplary Visualization

- Exemplary plot for S-HY and CONT-S:

  Aggregated power residuals for failed runs:
  - blue: supernodes
  - red: aggregation centers for demand nodes



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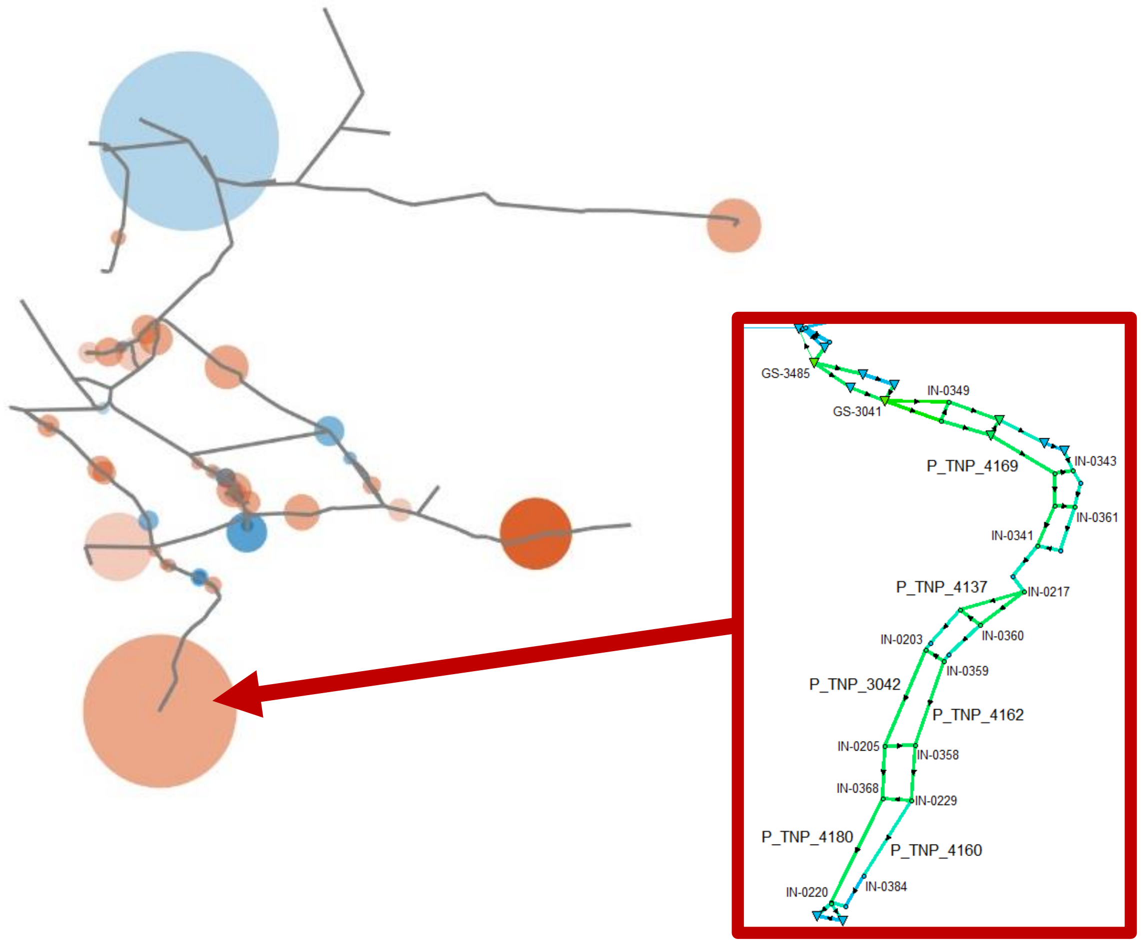
Results for partDE-Hy – Discussion

- Remedies for the North and the middle:
  - more H_2 injection nodes (possible)
  - gas storages (dito)

- Southern part critical:
  - natural storages & H_2 injection nodes far away
  - → build storages
  - → analyze neigh-boring countries as well!



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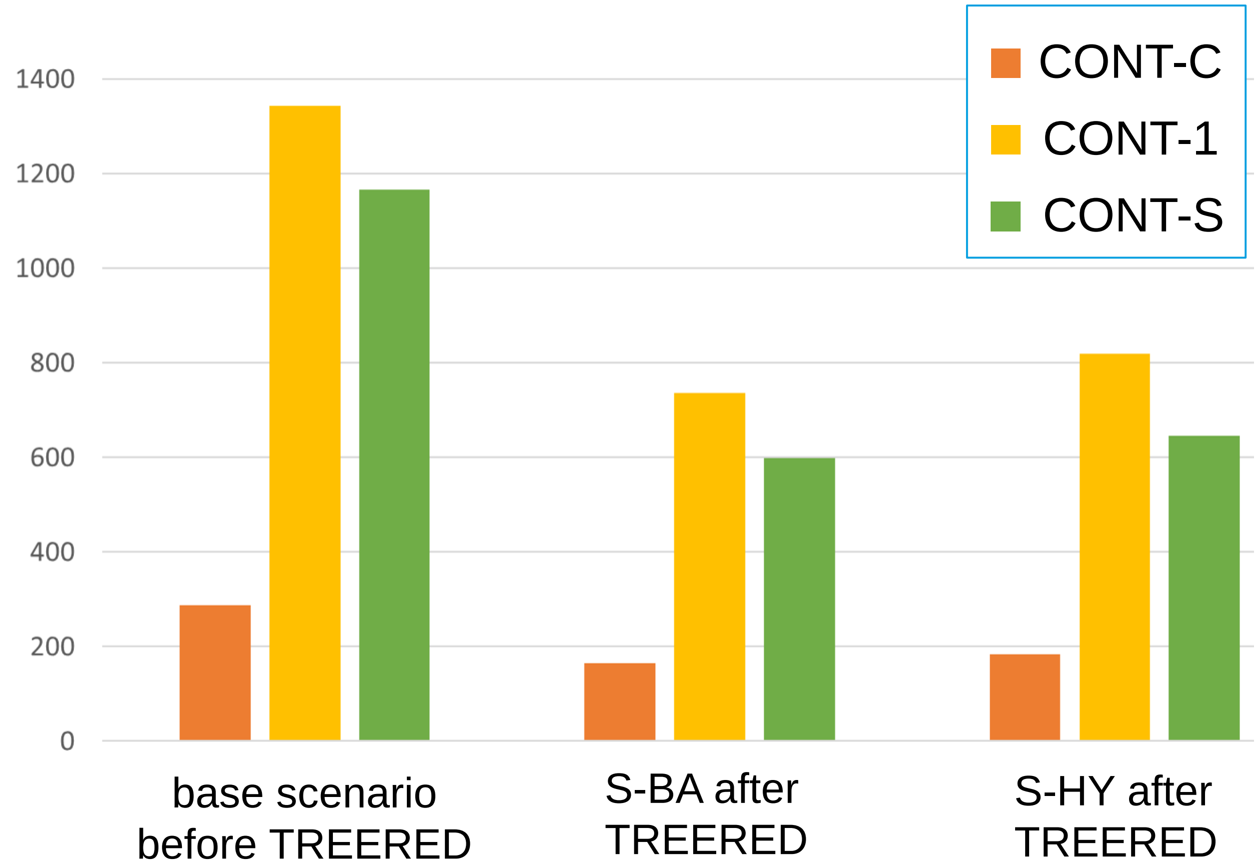
Results for partDE-Hy – Performance

- Run times [sec]
  - standard laptop, 4 years old
  - timings without parallelization (neither for the ensemble nor per simulation run!)
  - Runs numerically demanding due to the outages!

→ fast enough! ←



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Conclusions

- Novel methods for contingency analysis developed
  - CONT-C provides a quick overview on most critical scenarios w.r.t. large supplies, compressor stations and regulator stations
  - CONT-1 and CONT-S employ supernodes, in addition
  - CONT-1 provides a much more detailed analysis compared to CONT-C. It „simplifies“ supernode outage though – just one edge at a time
  - CONT-S considers outage of whole supernodes – more compact, and might be more realistic in practice → deeper analysis: future work!
- Prototypes already integrated in MYNTS
- Even on a rather slow standard laptop, all analysis methods can be performed in a reasonable time thanks to TREERED
- Large speedups possible on multi-core machines or clusters since the ensemble simulation can be parallelized trivially here!

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Thanks for Your Attention

www.mathenergy.de

tanja.clees@scai.fraunhofer.de

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