Identification of the main contributors to the security of supply in a gas transmission network

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JRC sites

Headquarters in Brussels and research facilities located in **5 Member States:**

- Belgium (Geel)
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- Spain (Seville)

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Outline

- Security of gas supply in Europe
- ProGasNet approach
- The study case
- Simulation results
- Conclusions & Discussion

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Background: policy support activity

Around 25% of all energy used in the EU comes from natural gas;

Many EU countries import nearly all of their gas supply, and some of them import from a single country or supply route;

Disruptions caused by infrastructure failure or political disputes can pose a serious risk to security of supply: complete stop of gas supply to EU via Ukraine in 2009, Baumgarten gas hub accident in 2017.

EU Regulation 994/2010

- requires to
  - perform risk assessment
  - prepare preventive and emergency plan
- introduces N-1 criterion as security of supply indicator

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Security of natural gas supply

CEF – Connecting Europe facility, managed by the EC, to fund energy and transport interconnection projects in the EU

Stress tests coordinated by the EC in 2014 revealed that many Member States still have high risk of severe disruption to gas supplies.

Energy Security strategy, May 2014.

EU Regulation 2017/1938, in force since October 2017

promotes solidarity among the EU Member States in case of gas supply crisis

Further initiatives: **Resilient Energy Union**

Probabilistic **Gas Net**work (ProGasNet) Simulator

Under development to quantify security of supply situation

Based on max- flow algorithm and Monte Carlo

Was applied to most vulnerable regions in the EU

Due to sensitivity of the data obtained directly from TSOs,
no geo-location can be disclosed

ProGasNet Approach

Input parameters for ProGasNet:

- Transmission Pipeline Length and Maximum Capacity matrices
- Peak demands at nodes
- Failure likelihood of facilities (LNG terminals, Compressor Stations, Storages) and pipeline segments
- Cross-border input capacity

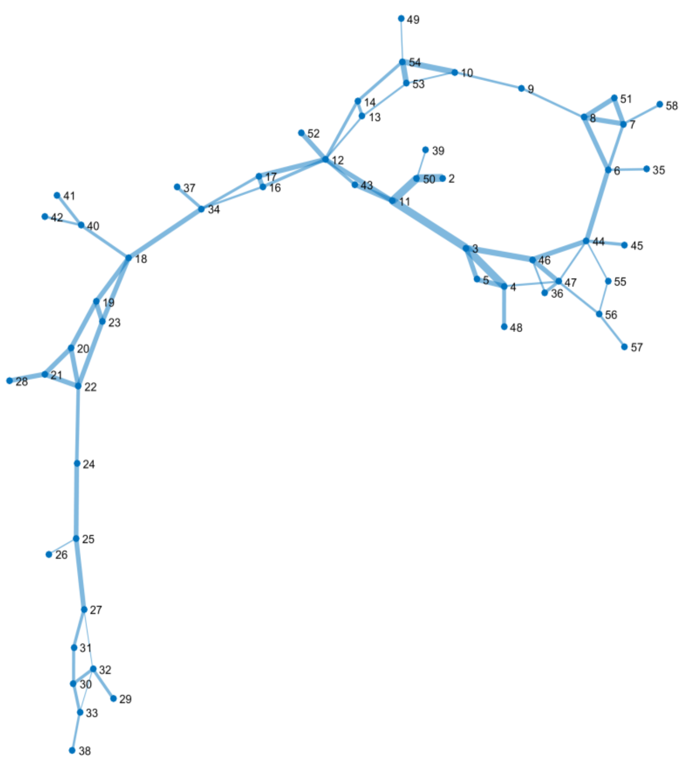
1 million of Monte Carlo runs for 1-day gas supply snapshot

The simulation results reflect peak demand situation to last for a period of one month

Max-flow is applied in each model run

Validation of the results with physical flow modelling software SynerGEE

Study case network



Node	Type	Capacity, mcm/day	Failure frequency, yr^{-1}
2	Pipeline	31	N/A
10	LNG	10	f(C=0)=8.3E-02 f(C=5)=0.125
11	Pipeline	7	N/A
19	UGS	30	f(C=0)=4.6E-02 f(C=15)=6.25E-02
29	Pipeline	4	N/A
38	Pipeline	2	N/A

The total maximum supply capacity **84** mcm per day.
The total network peak demand is **46** mcm per day

Scenario A: All available sources operate
Scenario B: Node 2 disruption
Scenario C: Node 29 & 38 disruption
Scenario D: Node 2, 29 & 38 disruption

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Simulation results - tables

Table 3: Probabilistic results for scenario A – all sources are available

Region	P(X=0)	P(X<0.2D)	P(X<0.5D)	P(X<0.8D)	P(X<D)
All Network	0	0	3.6E-05	4.4E-03	1.6E-02
Country 1	0	1.0E-06	4.2E-03	4.3E-03	5.2E-03
Country 2	0	0	1.4E-05	3.9E-03	5.8E-03
Country 3	0	0	1.0E-05	1.0E-05	2.9E-04
Exports	8.7E-05	8.6E-03	8.7E-03	8.7E-03	8.9E-03
Sum Country 1-3	0	0	1.4E-05	4.3E-03	1.1E-02

Table 4: Probabilistic results for scenario D: supply sources 2, 29 and 38 are unavailable

Region	P(X=0)	P(X<0.2D)	P(X<0.5D)	P(X<0.8D)	P(X<D)
All Network	3.0E-05	7.6E-05	4.0E-03	3.5E-02	1
Country 1	3.1E-05	7.4E-05	1.5E-02	3.2E-02	3.6E-02
Country 2	7.4E-05	7.6E-05	3.9E-03	3.9E-03	5.8E-03
Country 3	4.7E-03	5.2E-03	1.0E-02	1.1E-02	1.1E-02
Exports	7.4E-03	1	1	1	1
Sum Country 1-3	3.0E-05	7.6E-05	4.0E-03	2.0E-02	4.0E-02

Table 5: An average volume of the gas unserved (mcm/d) for all scenarios

Region	A	B	C	D
All Network	0.14	7.77	0.16	7.83
Country 1	0.042	0.22	0.042	0.23
Country 2	0.026	0.033	0.026	0.033
Country 3	5.9E-05	6.5E-05	0.027	0.042
Exports	0.068	7.52	0.068	7.52

Simulation results - plots

Figure 2: CDF plot for the whole network demand including exports

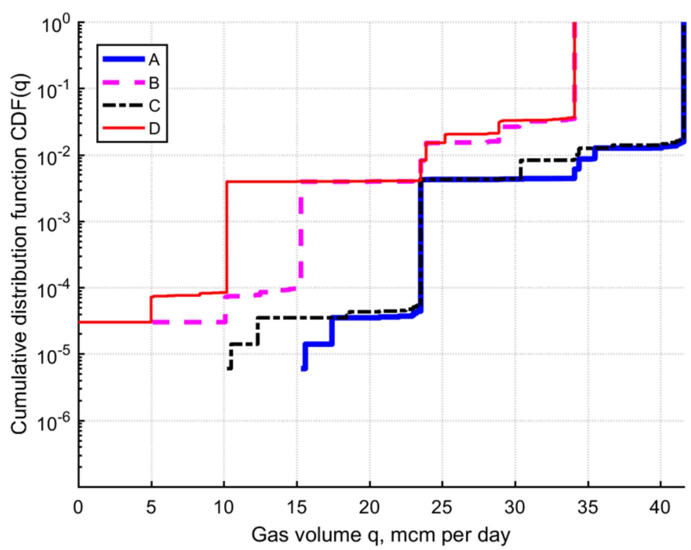
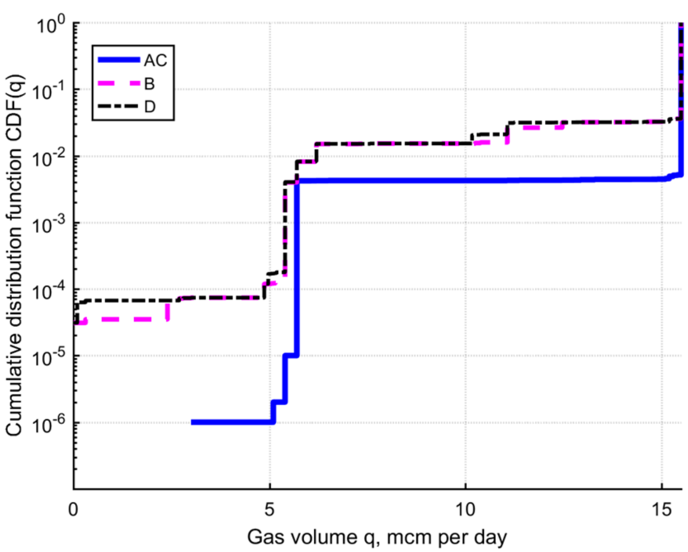


Figure 3: CDF plot for the Country 1



Main contributor analysis for supply X=0 & X<0.2D mcm/d

Supply (mcm/d)	Frequency	Scenario D: Contributors of P(X=0)=3.00e-05
0	3.00E-05	Node(10) Node(19)
Supply (mcm/d)	**Frequency**	**Scenario B: Contributors of P(X<0.2D)=3.00e-05**
5.1	3.00E-05	Node(10) Node(19)
Supply (mcm/d)	**Frequency**	**Scenario D: Contributors of P(X<0.2D)=7.60e-05**
4.87	3.90E-05	Node(10) Node(19)
0	3.00E-05	Node(10) Node(19)
5.04	2.00E-06	Node(19) Line(10, 54)
4.87	1.00E-06	Node(10) Node(19) Line(3, 11)
6	1.00E-06	Node(19) Line(14, 54)
4.87	1.00E-06	Node(10) Node(19) Line(19, 20)
4.87	1.00E-06	Node(10) Node(19) Line(11, 43)
6.5	1.00E-06	Node(19) Line(12, 14)

Main contributor analysis for supply X<0.8D mcm/d

Supply (mcm/d)	Frequency	Scenario A: Contributors of P(X<0.8D)=4.26e-03
23.4	3.90E-03	Line(3, 11)
23.4	7.80E-05	Node(12) Line(3, 11)
23.4	4.20E-05	Node(10) Line(3, 11)
23.4	3.40E-05	Node(11) Line(3, 11)
23.4	2.80E-05	Node(10) Line(3, 11)
17.3	1.80E-05	Node(19) Line(3, 11)
24.2	1.70E-05	Node(10) Line(11, 50)
23.4	1.50E-05	Node(19) Line(3, 11)
23.9	1.20E-05	Node(10) Line(2, 50)
23.4	8.00E-06	Line(3, 11) Line(29, 32)

Supply (mcm/d)	Frequency	Scenario C: Contributors of P(X<0.8D)=8.16e-03
23.4	3.90E-03	Line(3, 11)
22	3.64E-03	Node(19)
22	8.20E-05	Node(12) Node(19)
23.4	7.80E-05	Node(12) Line(3, 11)
23.4	4.20E-05	Node(10) Line(3, 11)
22	3.90E-05	Node(10) Node(19)
22	3.90E-05	Node(11) Node(19)
23.4	3.40E-05	Node(11) Line(3, 11)
22	3.00E-05	Node(10) Node(19)
23.4	2.80E-05	Node(10) Line(3, 11)

Supply (mcm/d)	Frequency	Scenario B: Contributors of P(X<0.8D)=1.53e-02
23.9	6.56E-03	Node(10)
23.4	3.90E-03	Line(3, 11)
15.2	3.64E-03	Node(19)
25.3	1.74E-04	Line(18, 34)
23.9	1.43E-04	Node(10) Node(12)
15.2	8.20E-05	Node(12) Node(19)
23.4	7.80E-05	Node(12) Line(3, 11)
23.9	6.20E-05	Node(10) Node(11)
25	4.40E-05	Node(10) Node(19)
23.4	4.20E-05	Node(10) Line(3, 11)

Supply (mcm/d)	Frequency	Scenario D: Contributors of P(X<0.8D)=2.04e-02
23.9	6.56E-03	Node(10)
25.1	4.89E-03	Node(19)
23.4	3.90E-03	Line(3, 11)
10.1	3.64E-03	Node(19)
25.3	1.74E-04	Line(18, 34)
23.9	1.43E-04	Node(10) Node(12)
25.1	1.00E-04	Node(12) Node(19)
10.1	8.20E-05	Node(12) Node(19)
23.4	7.80E-05	Node(12) Line(3, 11)
23.9	6.20E-05	Node(10) Node(11)

Main results

Main contributor analysis results for Country 1 are presented in the paper

Main contributor analysis for Countries 2 and 3 were performed

Although further importance measures need to be developed and further researched, already from these preliminary results it is obvious that **pipeline (3,11) is among the most important network elements**. The pipeline (3,11) is a short distance pipeline connecting compressor station (Node 11) to many large demand nodes. It is a pipeline which makes only less than 1% of the total length of the network and is the first candidate to be protected or parallelized. If (3,11) were unavailable, large consumer nodes would have cut-off from the supply sources.

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Conclusions

The risk assessments results show that in general all countries are relatively well supplied under scenario A when all sources are assumed to operate.

However, complete loss of pipeline supply (scenario D) is the worst case scenario for the whole region and further network development projects are needed.

The main contributor analysis study identifies pipeline (3,11) as the most important network element. The other main risk contributors are the gas supply sources: Node 19 and Node 10.

Thanks

Questions?

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