MAINTAINING SAFETY IN FUTURE GAS SYSTEMS
The Need to Include Systemic Risk Assessments

Ben Riemersma
Delft University of Technology
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How can we assess risks in complex gas systems?
Outline

- Gas Systems
- Risk Assessments
- Conclusion
Gas Systems (1/2)

Conventional Gas System

- Production
- Transmission
- Distribution
- Consumption
Gas Systems (2/2)

- Increasingly characterized by
  - Non-linear interactions
  - Feedback loops
  - Interconnected subsystems
Gas Booster

Natural gas producer → High Pressure Gas Grid

- Medium Pressure Gas Grid
- Medium Pressure Gas Grid
  - Low Pressure Gas Grid
  - Low Pressure Gas Grid
Gas Booster

- Natural gas producer
- High Pressure Gas Grid
  - Medium Pressure Gas Grid
    - Biogas producer
      - Low Pressure Gas Grid
      - Low Pressure Gas Grid
  - Medium Pressure Gas Grid
Gas Booster

Natural gas producer → High Pressure Gas Grid

High Pressure Gas Grid → Medium Pressure Gas Grid

Medium Pressure Gas Grid

Medium Pressure Gas Grid

Low Pressure Gas Grid

Low Pressure Gas Grid

Biogas producer
Risk Assessments

- Hazard and Operability Study (HAZOP)
  - Executed by grid operator
  - Focus on gas booster

- System-Theoretic Process Analysis (STPA)
  - Executed with grid operator
  - Focus on effects of gas booster
# Pressure: Hazards and Accidents

<table>
<thead>
<tr>
<th>HAZOP</th>
<th>STPA</th>
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<tbody>
<tr>
<td><strong>Incoming pressure too high</strong></td>
<td><strong>Gas pressure in source grid leaves</strong></td>
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<tr>
<td>• Unfiltered gas in system</td>
<td>acceptable boundary levels</td>
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<td>• Gas escapes system</td>
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Pressure: Hazards and Causes

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- 4 bar grid pressure too high
- Pressure regulator defective
- Pressure regulator out of spec
- DSO does not send initiate compress command (cmd.) when source grid pressure exceeds 3.8 bar
- DSO waits too long to send compress cmd. when source grid pressure exceeds 3.8 bar
- DSO stops compress cmd. when source grid pressure exceeds 3.8 bar
- DSO does not increase compress cmd. when source grid pressure exceeds 3.8 bar
- DSO waits too long to increase compress cmd. when source grid pressure exceeds 3.8 bar
- DSO decreases compress cmd. when source grid pressure exceeds 3.8 bar
Pressure: Hazards and Causes

HAZOP

Incoming pressure too high

• 4 bar grid pressure too high
• Pressure regulator defective
• Pressure regulator out-of-spec

STPA

Gas pressure in source grid leaves acceptable boundary levels

UCA-1-SCENARIOS

• Software is installed so that abort/decrease cmd. overrides initiate cmd. (possible conflicting parameters: destination grid pressure > 8.2 bar; gas is off-spec)
• Process model regarding source grid pressure is wrong
• Process model regarding destination grid pressure is wrong
• Process model regarding gas quality is wrong
• Control algorithm sends inappropriate CA based on inconsistent process model or faulty design
• Hostile takeover (computer hack) leads to inappropriate CA
• Initiate cmd. not (or too late) received by remote control
• Remote control delays sending initiate cmd.
• Compressor fails to follow up on initiate cmd.
• Off-spec gas is detected at compressor (i.e. continuous gas quality sensor is defective; power outage but gas keeps flowing; shut-off valve is defective)
• Gas that is sent to the grid becomes off-spec before it reaches the compressor
• Compressor failure
• Power outage (but biogas production continues)
• Changing supply and demand increase gas pressure in segments of the grid not registered by the sensor
• Sensor fails to measure grid capacity correctly
• Sensor fails due to power outage
• Sensor sends faulty or no information regarding grid pressure
• Mechanical stop is shut in the compressor
• Multiple boosters (or large biogas producers) are connected to one destination grid and have priority
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## Quality: Hazards and Accidents

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<td><strong>Outgoing gas too warm</strong></td>
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<tr>
<td>• Gas escapes system</td>
<td>• Fire/Explosion</td>
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<td>• Gas degrades infrastructure and attached appliances</td>
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- DSO sends initiate compress cmd. when gas is off - spec
- DSO applies initiate compress cmd. too long when gas is off - spec
- DSO does not abort compress cmd. when gas is off - spec
- DSO waits too long to abort compress cmd. when gas is off - spec
- DSO sends increase compress cmd. when gas is off - spec
- DSO applies increase compress cmd. too long when gas is off - spec
- DSO does not decrease compress cmd. when gas is off - spec
- DSO decreases compress cmd. when gas is off - spec (instead of aborting)
- DSO waits too long to decrease compress cmd. when gas is off - spec
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Conclusion

• Systemic hazards not adequately covered by HAZOP
  • Separately identified by HAZOP team
• STPA complementary
  • “Not-yet-hazards”
  • Use of software
Questions?

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