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Resilience Assessment Case Study Of A Gas Network

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The paper presents results of SecureGas project, focusing on resilience assessment of a gas transmission network, taking realistic gas transmission network as a case study. The study addressed three aspects of gas transmission network resilience, identified by the operator as most important: (1) risk and resilience study of a pipeline hub by all hazards approach; (2) prioritization of valves for SCADA connection; (3) development of modern tools for methane detection by drones. The first two analysis cases were supported by steady state gas flow hydraulic model, developed within the project. The third study case included development of a drone capable to detect methane leakages by autonomous pilot free flight. Due to length limitation, details of the third study case will not be presented in the extended abstract.

The first study case presents a risk assessment study of a gas transmission system pipeline hub area of 1km radius including a gas compressor station. The study adopted all-hazards, all-threats approach by analysing in detail natural hazards likely to happen in the area (e.g. forest fire, extreme cold, hurricane), external events (loss of power), technical failures (e.g. pipeline corrosion, compressor failure, valve inadvertent closure), human errors (e.g. operators' actions, unauthorized ground works), intentional human malicious actions on site (terrorist acts) and cyber-attacks. The methodological basis for the study was HAZID type process (Mannan, 2012). The study used the results from gas network modelling for quantification of consequences in terms of security of supply in the whole gas network and in particular the pipelines inside the hub. The modelling results identify the most important pipeline sections of the hub for the security of supply in the whole network. Six single segments were identified under N-1 disruption scenario (unsupplied gas volume ranging from 39 to 5%) and eight double segment disruptions were identified from N-2 disruption scenarios (unsupplied gas volume ranging from 76 to 22%).The model was developed within SecureGas project and used for specific tasks (Ganter et al., 2024). In the risk assessment study, the following methodological steps were performed:

- Step 1: Identification of hazards and threats
- Step 2: Screening of hazards and threats for the area under study and historical failure data analysis
- Step 3: HAZID process with input from the modelling; Consequence (severity) and likelihood estimation
- Step 4: Risk matrix build-up
- Step 5: Findings and recommendations

The risk matrix of 59 elements (shown illustratively in Figure 1) was built from hazard evaluation table. The study concluded with 10 findings and 13 recommendations to be used for further decision making process.

The second study case aimed to develop a priority list of main valves of the gas transmission network that should be connected to SCADA for remote monitoring and control. Remotely controlled valves are necessary to quickly localize accidents, minimize methane release into atmosphere and enable rerouting of the gas flow to ensure security of supply. Although the highest system resilience is achieved when connecting all main valves, this process is long and therefore must be prioritized as not all valves have the same importance for the system operation. The priority list involved development of a multi-criteria decision tool (Vamanu et al., 2016) as many different parameters should be considered for connection of a valve to SCADA. Each parameter was quantified on a unified scale and then the total priority score was obtained by applying a specific weighting scheme. The following quantitative and qualitative criteria were used for the ranking: pipeline importance in terms of security of supply (Kopustinskas and Praks, 2018); pipeline diameter; type of customers served and demand volumes (protected, industrial); valve accessibility (distance to the roads); land use parameters and hazard zones (forest areas, flood areas, swamps); costs of installation and maintenance; networks topology (number of valves in close vicinity, within 300 meters). These criteria were further developed and applied for the valve topology in QGIS software, obtaining individual scores of some indicators directly from QGIS computational routines. The final priority list of 349 line valves was obtained by applying weights on individual indicators as assigned by experts under expert judgment techniques. The list was used by the system operator as quantitative input for further decisions.

Severity of consequence	Likelihood: Rare	Unlikely	Credible	Probable	Frequent
Very High					
High		N27, P1			
Medium	N6, N30	N1, N14, H3, I1, I7, I8		N12, E1, E5	
Low	N22, N29, E7	N2, N10, N11, N21, N24, N26, P3, P4, P5, P6, P7, P8, H1, H2, H4, H5, I2, I3, I4, I5, I6, I9	N7, N8, N9, N15, N18, N23, N25, E2, E4	N19, N28	N4, N5, N16, N17
Very low	E6, P2	E3		N3, N13, N20	

Fig. 1. Risk matrix visualisation of a pipeline hub.

The priority ranking of the valves for SCADA connection is an important operational task to help planning the network control activities. The methodology developed and implemented relies on correct information in the GIS geodatabases and therefore completeness and correctness of GIS geodatabases is essential for obtaining correct priority ranking of the valves. The application of the methodology illustrates how GIS geodatabase can be efficiently used to obtain important operational findings and results.

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