How to deal with the risk of natural hazards to pipelines and other gas infrastructure facilities

1. INTRODUCTION

Many different types of natural hazards can pose a risk to natural gas infrastructure. By definition natural hazards refer to those that are not caused by human activity. E.g. ground movements due to mining or construction activity, subsidence of the surface due to oil or gas exploration are not considered as natural hazards.

The EGIG database (https://www.egig.eu/reports) does not use "natural cause" as a primary failure cause for underground pipelines. In the primary causes "ground movement" and "other" some subcategories are present that can refer to natural hazards. These subcategories are: dike break, erosion, flooding, land slide, river and lightning.

The Emergency Events Database (EM-DAT) (http://emdat.be) gives a possible classification scheme for natural hazards. The following subgroups are mentioned: geophysical, meteorological, hydrological, climatological, biological and extra-terrestrial.

One type of natural hazards is geohazards and refers to geological conditions capable of causing damage. On the website of the EC project "PanGeo" (www.pangeoproject.eu) one can find an extensive description of the following natural geohazards:

- Deep ground motions
  - Earthquake (seismic) hazard
  - Tectonic movements
  - Salt tectonics
  - Volcanic inflation/deflation

- Natural ground instability
  - Landslide
  - Soil creep
  - Ground dissolution
  - Collapsible ground
  - Running sand/liquefaction

- Natural ground movement
  - Shrink-swell clays
  - Compressible ground

Also, erosion, either by wind or water (river, coastal) should be considered as a natural hazard possibly impacting gas infrastructure.

Some of the above-mentioned hazards seem on a first sight not relevant to gas infrastructure, e.g. biological and extra-terrestrial hazards. But a geomagnetic storm may have an impact on the data communication system; a rodent plague can cause serious damage to instrumentation/data cables.

Some other examples:

- Meteorological: extreme cold/hot temperature, wind, tornado, hail
- Hydrological: flooding, avalanches
- Climatological: wildfire

2. HOW TO DEAL WITH NATURAL HAZARDS?

As protection measures against natural hazards can have an extremely high cost, one should consider evaluating the risk of natural hazards in a systematic way, and in accordance with the company risk policy.

In general, the approach to deal with natural hazards is the same as with technological hazards. Some specificities must be considered though:

- They can have a very low probability of occurrence but a very high impact.
- They are strongly correlated to the geographical location of the infrastructure.
- Data for a specific location can be difficult to find.
- …

As many of these natural hazards are only relevant in specific geographical regions and locations, this implies that often a specific risk assessment should be done for a specific gas asset. This not only allows to take into account the local hazards and their local probability of occurrence, but also to take in account the criticality of the asset in the whole gas infrastructure network. The assessment could also help to define which subparts of an installation are more critical than others.

The physical impact on the gas infrastructure can be difficult to assess and appropriate expertise should be used. This may imply the use of specific software packages. The impact can be very different for different types of infrastructure (underground-aboveground). Besides the direct impact on the infrastructure, one should also assess the impact of the failure of the infrastructure. This is mostly done for five categories: health and safety, economic loss, environment, loss of supply and reputation.

To assess the local likelihood and severity of a natural hazard occurring, one should be familiar with the local situation. Information may be found in specific databases from Authorities, Universities or Research Centers (e.g. flood maps, landslide databases, seismic hazard maps, etc). In case of lack of information, it may be necessary to do a soil survey.

3. HOW TO PROTECT?

By constructing infrastructure according to design standards and company specifications, the infrastructure already resists against a wide range of natural hazards, to a certain extent. Therefore, it is important to know which conditions are within the design conditions of the installation and which ones should be considered as "extreme".

The types of protection measures can be divided in two categories: permanent measures and temporary measures. Besides this consideration, one should also decide whether to protect the complete asset or just to focus on subparts of the installation that are most critical.

4. PERMANENT MEASURES

1. **Design**: To adapt the design of components of the infrastructure to increase the resistance.

   E.g. modified mechanical properties of the pipeline (wall thickness, elastic and plastic properties), fire proof cables or actuators, increased safety factors for wind, snow, thermal or earthquake loading (cf. Eurocodes).

2. **Structural measures on asset level**: these are extra barriers that protect the gas infrastructure against the natural hazard.

   Examples: earth dam, ground/snow/water retaining wall, put certain components at an elevated level (e.g. electricity cabinet), conditioned room, avoid basements, in- or outside location

3. **Adaptations in the environment**: these measures usually have a great impact on the environment and not only affect the gas infrastructure. The impact of the measure in other domains (ecological, agriculture…) has also to be evaluated. Consultation with authorities and land owners is necessary. In general cost is very high and one should look for common interest with other parties.

   E.g. elevate dikes, storm water balancing tanks, improve ground properties (deep soil mixing, grouting, drainage, stone columns…), anchorage of slopes, gabions, groynes, remove trees/bushes …

4. Relocation of the gas infrastructure to a "lower risk" location, incl. changing pipeline depth.

5. Increase the network redundancy in a way that, in case of failure (Denial of Service) of one asset, the service can be completely/partially taken over by another asset.

5. TEMPORARY MEASURES

Temporary measures are typically put in place at a certain moment when the likelihood of a natural disaster becomes significantly higher (higher threat level).

Whether temporary measures can be effective depends on the speed at which the situation can evolve and on the time necessary to roll out the measures.

This requires permanent monitoring of the situation, so one will be alerted in time. This also requires the capability of mobilizing people and material when required. When determining the number of people and the amount of material required, one should assess the likelihood of having multiple situations requiring intervention at the same time.

1. Monitoring: monitoring ground movements (strain gauges, inclinometers, surface markers, satellite, ground/air patrolling…), monitoring weather forecasts and water levels, including automated alert messaging.

2. Use as much as possible the crisis organization structure and incident management routines that are in place for other type of "emergencies" (electricity black out, ICT failure, gas leak, pipeline rupture…)

3. Before the situation becomes critical, intervention teams can be put in pre-alarm to increase the speed of intervention.

4. Emergency plans should include protocols with authorities, to have clear allocation of duties and communication lines (incl. back-up lines).

6. CONCLUSION

The approach described in this paper provides a clear and transparent insight in the operator's recognition of the risks related to natural hazards and the way they can be managed. There are many similarities with the way operators deal with technological hazards, but some specificities must be considered. Because the "threat" of a natural event occurring can strongly alternate over time, well elaborated temporary measures are as valid as well designed permanent measures.

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