DIN - DEPARTMENT OF INDUSTRIAL ENGINEERING

PhD Course in Mechanics and Advanced Engineering Sciences (DIMSAI)

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Natural gas distribution network safety

PhD scholarship dedicated to the memory of Simone Messina

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Introduction

Despite the always higher use of renewables, Natural Gas (NG) has still a primary role in energy market particularly in residential and commercial sectors where, only in Europe, 323 TWh/year have been consumed on average in the period between 2008 and 2014 (Source Eurogas, 2015).

The importance of NG for energy supply in actual European scenario is represented by the size of networks (transmission and distribution) that reach a total length up to 2.214.471 km (figure 1) (Eurogas, 2015); Italian local distribution systems reach a length up to 258.303 km (AEEGSI, 2016) with an average installation density of 0,86 $\mathrm{km/km^2}$.

Therefore, the operation of this very branched system from ReMi (Regolazione and Misurazione) stations up to domestic fiscal meters is very complicated for operators and sector stakeholders especially in very high populated areas.

Even if NG distribution networks are installed in very different geographical areas, the minimum ***safety*** levels have to be ensured to minimize failure risk occurrence. NG networks differ each other from mechanic, environment and operating point of view but despite this, national regulation does not take it into account for the definition of inspection requirements. That is, even if the percentage of network monitored is increased of the 143% from the 2002 to the 2015 (AEEGSI, 2017), NG leakages identified and emergency calls have been almost constant for the period demonstrating possible improvements respect to actual safety programs (figure 2).

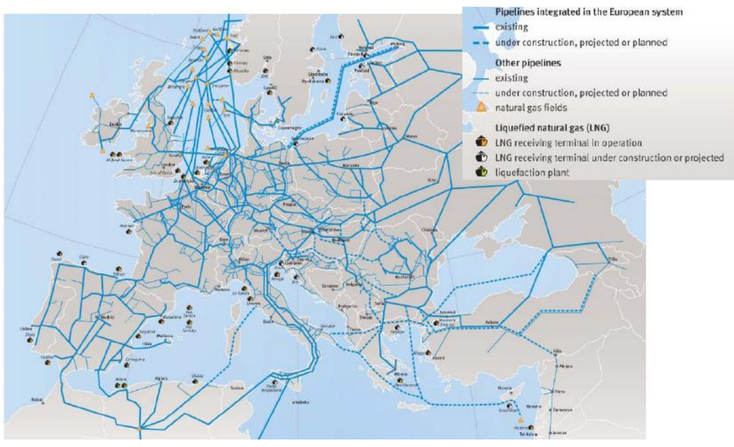

Figure 1. European Natural Gas transmission networks (pressure higher than 12 bar)

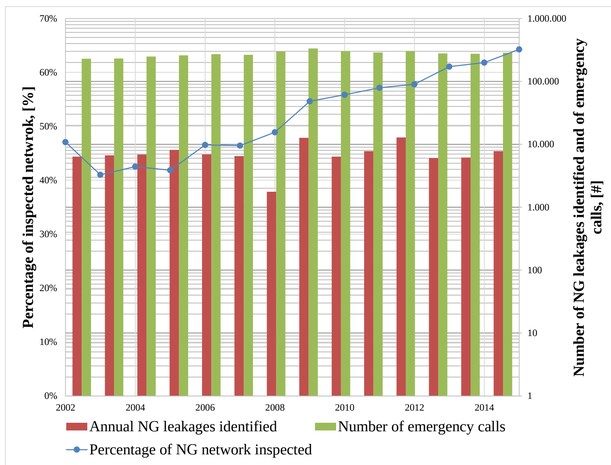

Figure 2. Annual percentage of network length inspected and number of NG leakages identified.

Project description

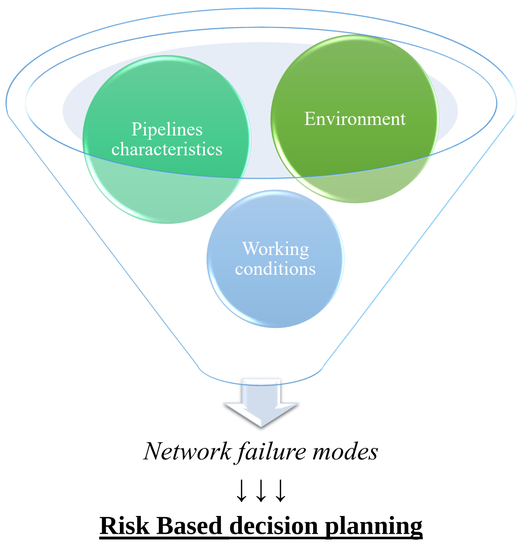

Figure 3. Risk based decision should be based on the specific condition of the network.

Research activities want to identify possible failure modes of NG networks and assess NG performances as a function of pipeline, environment and working characteristics (figure 3) to define a new approach for Risk Based decision planning.
The aim of the project is also the evaluation of new monitoring systems able to identify the occurrence of abnormal conditions and so reduce failure risk in the network.

Furthermore, new NG smart meters that measure / communicate data and intercept NG flow from remote location (figure 4a) are being installed up to 22 million of end users within the end of the 2018: being the massive roll out made without a complete experimental phase, several questions as battery effective life (figure 4b) and remote valve tightness after several working years are still unclear.
That is, both have to be carefully analysed to identify performances in real environment conditions: improvements will be proposed on the base of identified issues.

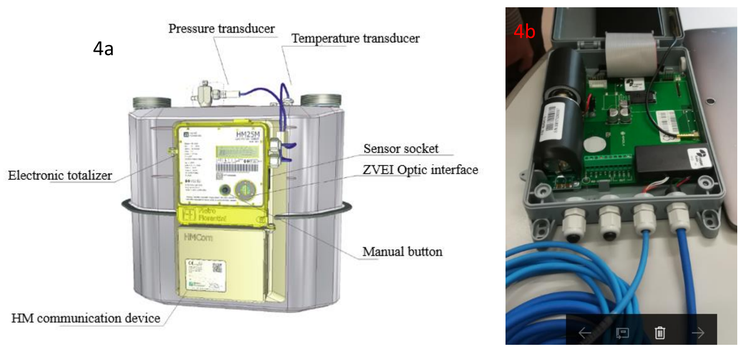

Figure 4. NG smart meter (a) and battery pack (b).

Results

1. NG distribution network characterization as a function of pipelines characteristics, environment and working conditions (figure 5) has been made;
2. NG networks failure identification (figure 6) as a function of network characteristics has been concluded;

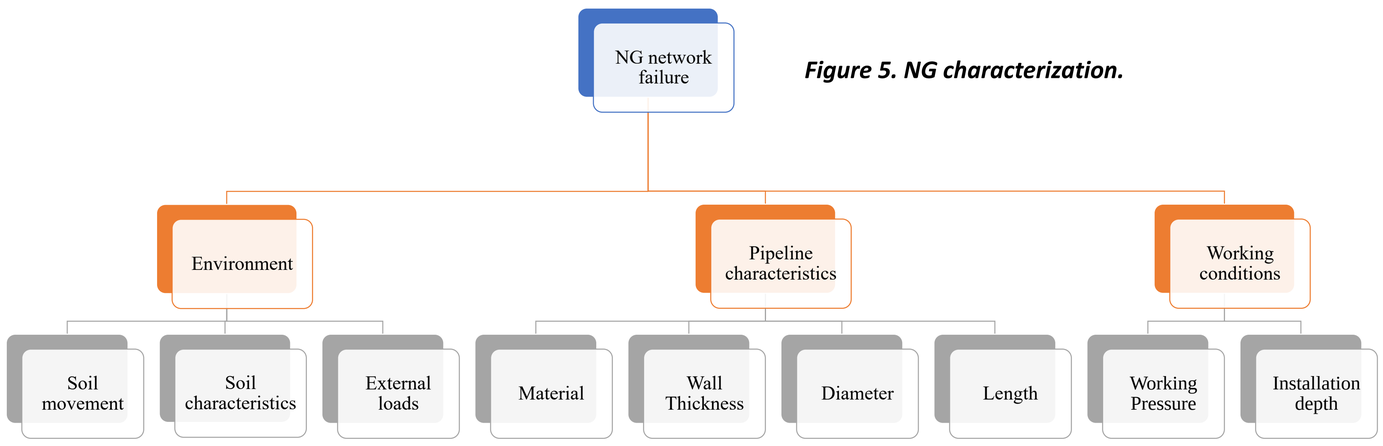

Figure 5. NG characterization.

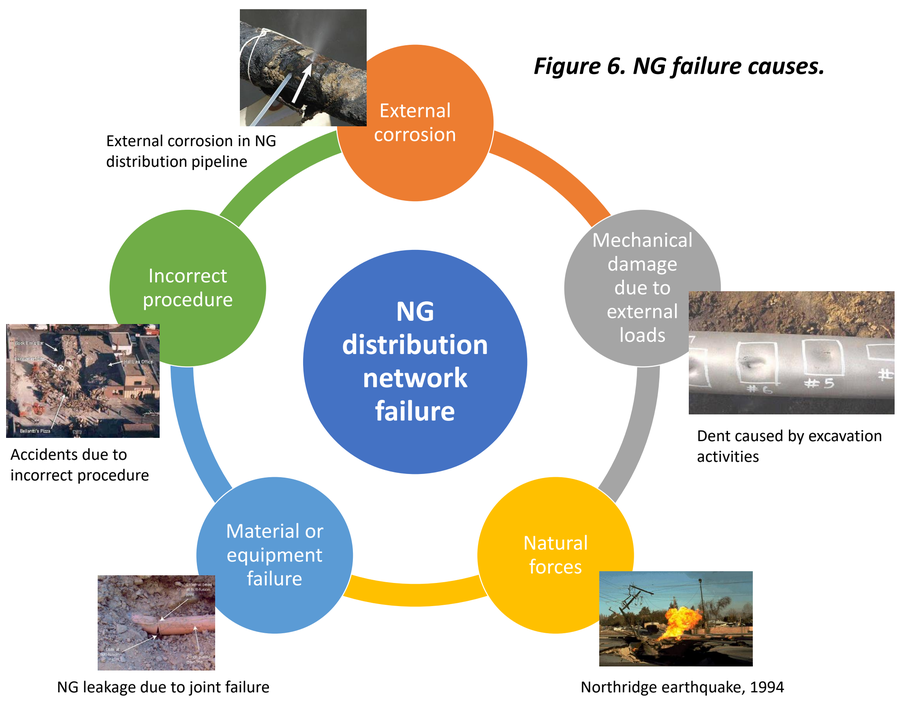

Figure 6. NG failure causes.

3. Analysis of repair rate (number of repair divided by pipeline length) in NG distribution is actually performed to define a method for pipeline risk classification useful to allocate available budget (figure 7);
4. Because of the high value of pipeline density in Italy (especially in landslide and hydraulic risk areas), research on the possible use of NG pipelines for soil movement monitoring has been started identifying two possible technologies for the scope (fiber optic cables and Global Positioning Systems – GPS);
5. It has been found that very few data are available in Italy about NG distribution accidents and failures. Efforts should be made in future to define reports useful to assess the condition of the network and so to define more specific inspection/maintenance plan;
6. Lithium batteries ($LiSOCl_2$ and $LIMN_2O_4$) are used in NG smart meter and their performance (operative life) depends on environment temperature and on electrical load (current amplitude and discharge profile - pulse or continuous discharge) (figure 8). It has been found that the batteries used in NG smart meter for domestic application ensure the required operative life.

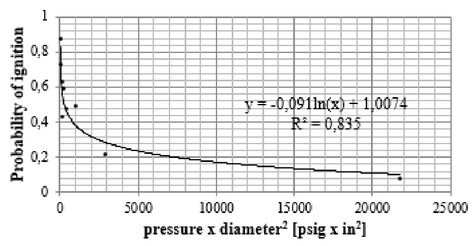

Figure 7. Probability of gas ignition after a leakage as a function of working pressure and diameter.

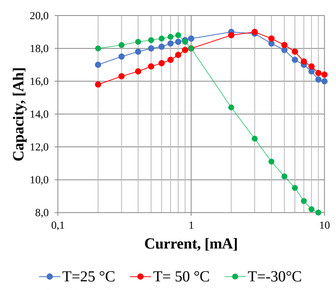

Figure 8. Typical battery capacity as a function of current and temperature.

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