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Review

Best practices to reduce methane emissions at gas transmission networks. A literature review and case studies

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Abstract

This paper studies methane emissions reduction at natural gas transmission systems. A literature survey on the topic is presented along with some characteristic case studies. Such case studies reveal that a significant reduction of methane emissions at gas transmission systems may be achieved with application of best practices, resulting in a large impact on decarbonization and environmental protection efforts. At a characteristic case study, the maintenance plan optimization of the scraper traps along a gas transmission network reduced methane emissions by 90%. Quantification of methane emissions reduction at the presented case studies may serve as quick reference for similar applications. The analysis aims to contribute to better understanding of methane emissions sources and the adoption of emissions reduction measures at gas transmission systems.

Keywords: methane emissions; gas network; transmission network; natural gas; greenhouse gases

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1. Introduction

Methane, the main component of natural gas, is one of the most important contributors to climate change and plays a dominating role in how fast the climate warms. Methane contributes to at least 25% of today's climate warming, and its concentration in the atmosphere continues to rise rapidly, in large part from anthropogenic sources [1]. Over the past decade atmospheric concentrations of methane have been increasing much faster than previously, and in 2020 at the fastest rate since records began in the 1980s [2]. The annual increase of the global atmospheric methane concentration is evident according to the reports of the Global Monitoring Laboratory [3]. Methane is a more potent greenhouse gas (GHG) than carbon dioxide, having a shorter atmospheric lifespan. Climate policies heavily emphasize actions that benefit the climate in the long-term such as decarbonization and reaching net-zero emissions [4].

Gas transmission operators, worldwide, are carrying out intensive programs on the quantification of the total methane emissions in their activities and are designing mitigation measures for methane emissions reduction. The large gas supply chains are significant sources of methane emissions, as reported by Cooper *et al*. [5], with a high degree of uncertainty in emissions data. More efforts should be put into collecting facility-specific emissions data and improve the transparency in reporting emissions to reduce uncertainties. These would aid in better emission reporting and facilitates the development of effective emission abatement strategies.

This paper presents a literature survey on methane emissions reduction at transmission systems. Also, characteristic case studies from gas transmission companies and from DESFA (www.desfa.gr), the Hellenic gas transmission system operator, are discussed. Methane emissions of each case study are quantified to serve as quick reference for similar applications.

2. Literature Review

The Oil & Gas Methane Partnership 2.0 [6] is a multi-stakeholder initiative launched by United Nations Environment Programme and the Climate and Clean Air Coalition, as a voluntary initiative to help companies reduce methane emissions in the oil and gas sector. This initiative is a comprehensive, measurement-based reporting framework that improves the accuracy and transparency of methane emissions reporting in the oil and gas sector. Through participation in the OGMP associated reporting, companies were provided with a credible mechanism to address their methane emissions systematically and responsibly, and to demonstrate this systematic approach and its results to stakeholders. DESFA has adhered to this partnership with 100 well known enterprises worldwide, of the oil & gas business [7].

The methodologies for evaluating the methane emissions from the gas systems are based on statistic approaches using specific "activity factors" (the emitting equipment population) and "emission factors" (the frequency of emitting events). Lately direct measurements of methane emissions are used to increase confidence of estimation. Methane emissions are divided in three macro categories [8]:

- Fugitive emissions;
- Vented emissions (including pneumatic emissions);
- Emissions from incomplete combustion (unburnt).

Fugitive emissions are the unintentional releases to the atmosphere resulting from leaking equipment, whilst Vented emissions are the planned releases of gas to the atmosphere as a result of process design.

Lechtenböhmer *et al.* [9] reports that methane emissions from a long-distance gas network (the Russian network) are approximately 0.6% of the natural gas delivered. Mitigating these emissions can not only earned carbon credits but can also create new revenue streams for the operator in the form of reduced costs, increased gas throughput and sales. To support the effort of methane emissions management along oil and gas supply chains, the Methane Guiding Principles partnership [10], a coalition of industry, international institutions, nongovernmental organizations, and academics, has developed a series of Best Practices. These Best Practices focus on minimizing methane emissions through engineering, design and construction, as well as reducing methane emissions from flaring, energy use, equipment leaks, venting, gas driven pneumatic equipment and operational repairs.

Sources of methane emissions for midstream and downstream gas segments (*i.e.*, transmission networks, underground gas storages, LNG regasification terminals and distribution networks) are listed in Table 1 [6,8]. The transmission segment of a natural gas system comprises the transmission pipeline networks, the compressor stations and the metering and pressure-regulating stations. Among the available methane emissions abatement technologies are [11]: leak detection and repair surveys, convert gas pneumatic controls to instrument air, re-injection of natural gas at maintenance and repair works, lower gas line pressure before maintenance, replace continuous gas vent, replace wet seals with dry seals in centrifugal compressors, use nitrogen instead of natural gas at seals of compressor units, replace gas operated safety block valves. Some of these abatement technologies to reduce methane emissions at transmission networks are discussed and quantified below.

Table 1 Sources of methane emissions for midstream and downstream Gas segments [6,8].

Type of emissions	Sources of methane emissions	
Fugitives	Leaks from components (loss of tightness)	
	Permeation	
Vented	Operational emissions	Purging & venting (maintenance, process, commissioning & decommissioning)
		Regular emission technical devices (pneumatic devices, gas analysers…)
		Starts & stops
	Incidents / emergency situations	
Incomplete combustion	Gas combustion devices (turbines, engines, boilers…)	
	Flaring	

2.1 Leak detection and repair (LDAR)

Leak detection and repair (LDAR) refers to the process of locating and repairing fugitive leaks. LDAR encompasses several techniques and equipment types (IR cameras, sniffers, *etc*.). According to Ravikumar *et al.* [12] the total methane emissions reduced by 44% after one LDAR survey at natural gas facilities, combining a reduction in fugitive emissions of 22% and vented emissions by 47%. Furthermore, more than 90% of the leaks found in the initial survey were not emitting in the re-survey, suggesting high repair effectiveness. However, fugitive emissions reduced by only 22% because of new leaks that occurred between the surveys. This indicates a need for frequent, effective, and low-cost LDAR surveys to target new leaks.

2.2 Replace wet seals with dry seals at compressors

Compressors and compressor-related equipment (Figure 1) are usually the largest methane emission sources at gas transmission systems [13]. Subramanian *et al.* [14] reports equipment and site-level methane emissions measurements from 45 compressor stations in the transmission and storage sector of the US natural gas system. Direct measurements of fugitive and vented sources were combined with site-level methane emissions data. At most sites, these two independent estimates agreed within experimental uncertainty. Compressor vents, leaky isolation valves, reciprocating engine exhaust, and equipment leaks were major sources, and substantial emissions were observed at both operating and standby compressor stations. Johnson *et al.* [15] conducted leak and loss audits for methane emissions at three natural gas compressor stations and two gas storage facilities. Methane analyzers, bag samples, and infrared analyzers were employed for emissions rate quantification. All sites had a combined total methane emissions rate of 94.2 kg/h.

Centrifugal compressors have seals along their shaft to keep gas from escaping. Wet, or oil-lubricated, seals by design result in substantial methane leakages. Dry seals operate mechanically without seal ring lubrication, which in its turn reduces gas leakage [16]. Replace wet seals with dry seals at compressors is a best practice to reduce methane emissions.

Figure 1 A centrifugal Gas Compressor of DESFA SA.

2.3 Re-injection of natural gas

At certain cases of maintenance or repair works at transmission networks a large section of a pipe must be depressurized. Instead of venting to the atmosphere, the gas contained in the section of pipe can be removed to be reinjected it in a neighboring section with the help of mobile compressor unit [10]. Figure 2 illustrates such a process already followed by some gas transmission system operators [17].

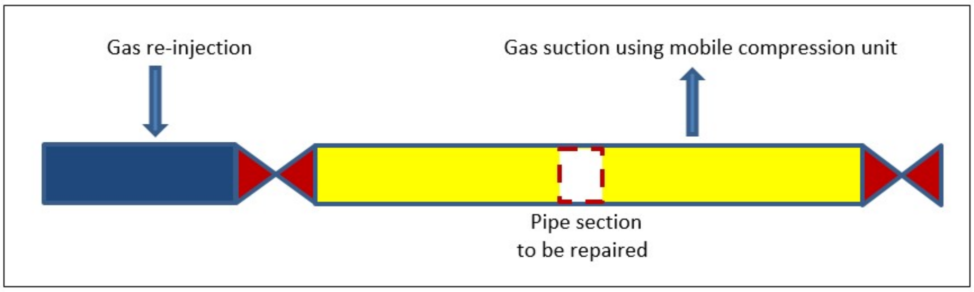

Figure 2 Re-injection of natural gas at large pipeline repair works.

3. Case Studies

3.1 Replace continuous gas Vent with nitrogen

Not neglecting the other methane emissions macro categories, the vented emissions have a significant part at the total and their mitigation measures have a direct and large impact. At large gas facilities emergency vent lines are continuously purged with gas to prevent air introduction to the pipes. Nitrogen can be used instead of gas for this purging. Figure 3 depicts the vent stack of DESFA's Sidirokastro border metering station of a height 10 m, vent tip length 2 m and width 0.2 m. This vent stack has a design purge gas consumption 0.51 Nm^3/h (Operation & Maintenance manual of DESFA's Sidirokastro station), which results to methane emissions of 3200 kg/y, a released methane quantity that can be avoided with the replacement of gas with nitrogen.

Figure 3 Continuous Vent stack.

3.2 Replace gas with air at gas operated control valves

The gas consumption of a 24" ANSI 600 pressure/flow control valve, gas operated with spring opening piston actuator, is 1.3 m^3/hr for the valve positioner at 7 barg supply. Also, for the I/P converter the gas consumption is 0.16 m^3/hr and for one complete stroke (open to close) of this valve the gas consumption is 0.038 m^3. (Operation & Maintenance manual of DESFA's Sidirokastro station). When a continuous operation of this valve is considered, the maximum yearly methane emissions are estimated to 9200 kg/y, which can be avoided using instrument air instead of gas for the valve operation. Indeed, some years ago, DESFA replaced such gas operated valves at Sidirokastro border metering station with air operated valves (Figure 4) to reduce methane emissions.

Figure 4 Air operated flow control valve.

3.3 Optimize preventive maintenance program

To minimize Venting and to adopt best practices, DESFA reduced the frequency of the preventive internal inspection of the scraper traps along the gas transmission network from the initial frequency of six months to two years and recently to five years. Internal inspection requires depressurization and gas venting (Figure 5). This optimization of the maintenance plan reduced methane emissions for this specific maintenance operation by 90% as Table 2 indicates.

Table 2 Methane emissions reduction due to the optimization of DESFA's scraper traps maintenance plan.

Preventive maintenance frequency	Total Methane emissions (kg/y)	Methane emissions reduction (%)
6 months	120000	–
2 years	30000	75
5 years	12000	90

Figure 5 Gas venting during depressurization of a DESFA's scraper trap.

4. Conclusions

Application of best practices may result in a significant reduction of methane emissions in a gas transmission system [2,18]. This paper is gathering the scarce literature and present a literature survey on this topic. Also, some characteristic case studies are presented. Quantification of methane emissions reduction at the case studies offers a quick estimation for similar cases at gas networks. For example, the total methane emissions reduced by 44% after one LDAR survey at natural gas facilities. Also, optimization of the maintenance plan reduced methane emissions from the operation of the gas network scraper traps inspection by 90%.

This analysis aims to contribute to better understanding of methane emissions sources and the adoption of methane emissions reduction measures at gas transmission systems.

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Competing Interests

The authors have declared that no competing interests exist.

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