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Investigate Method to Reduce Methane Emission during Maintenance Operations from Algerian Natural Gas Transportation

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Abstract— Methane concentration in the atmosphere has critically increased recently, its account for about 50% of the greenhouse gases (GHG) emissions. Increasing environmental concern and global warming have made it become an imminent consideration. The energy sector is the second largest contributor to methane emissions. The emissions of natural gas from gas transportation pipeline are an important factor for global warming. For this article we try find a way for preventing of waste this source because of economical aspect and environmental problems. First we calculate the volume of gas venting from pipeline and then get quantity of money value of this gas then we suggest a mobile compressor for saving this gas. Pipeline pump-down technique with portable compressor solution instead of venting will mainly allow 54.873 million m^3 gases saving, which costs about 11.628 million USD and benefits justified purchase of 4 portable compressors.

Keywords— Greenhouse gases, Methane emissions mitigation, Natural gas pipelines transportation, Gas venting, Portable compressor.

1. INTRODUCTION

Methane (CH_4) is one of the six Greenhouse gases (GHGs) being mitigated under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). The others are carbon dioxide (CO_2), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Atmospheric concentration and sources of CH_4 are not particularly well understood or well quantified, and they are highly disputable (Frankenberg et al., 2005; Miller et al., 2013). Also, official inventories underestimate actual CH_4 emissions (Brandt et al., 2014) despite, yet again, a rising global trend of CH_4 (Nisbet et al., 2014). According to the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2007), the global atmospheric concentration of CH_4 rose from a pre-industrial value of 715 parts per billion (ppb) to 1732 ppb in the early 1990s and 1774 ppb in 2005, i.e. a rise of about 150% (Anifowose and Odubela, 2015). This is of concern given that the lifetime of CH4 once released into the atmosphere is about 12 years (Xu et al., 2013), and it is 28 times more potent at trapping atmospheric heat than CO_2 over a 100 year timescale (IPCC, 2006). Clearly, methane is crucial in the mitigation of global warming as its reduction will support an average global temperature rise of not greater than 2°C (US EPA, 2014). A significant fraction of GHG originates from the use of energy, primarily because fossil fuels (oil and natural gas) currently satisfy most of the global energy demands (Litto et al., 2007). Of the fossil fuels, natural gas has the lowest emissions of GHG per unit of energy, and there is much interest in switching from oil to gas. However, while natural gas is significantly cleaner than other fossil fuel (combustion GHG emission from natural gas per unit energy produced is 25% less than oil), non-combustion GHG emission (fugitive emissions) occurs during the process of extraction, production, processing, transmission, storage and distribution (Lechtenböhmer et al., 2007; Salomons et al., 2004).

Algeria's domestic natural gas pipeline system transports natural gas from Hassi R'Mel fields and processing facilities owned by Sonatrach, to export terminals and liquefaction plants along the Mediterranean Sea. It is divides into three main domestic pipeline systems:

❶The Hassi R'Mel to Arzew system is a collection of pipelines that move natural gas from HassiR'Mel to the export terminal and the LNG plant at Arzew. The system also includes an LPG pipeline. ❷The Hassi R'Mel to Skikda system transports natural gas from the Hassi R'Mel fields to the Skikda LNG plant. ❸The Alrar to Hassi R'Mel system transports natural gas produced in the Alrar and the southeastern region to the Hassi R'Mel processing facilities (Sonatrach, 2014a, 2014b). The network includes also three transcontinental gas pipelines ; one to Italy. The largest pipeline, Pipeline Enrico Mattei (GEM), came online in 1983 and runs 1.025 miles from Algeria to Italy via Tunisia. GEM's capacity is more than 1.3 Tcf/year and it is jointly owned by Sonatrach, the Tunisian government, and Eni. The Pedro Duran Farell (GPDF) pipeline started in 1996 and travels 325 miles to Spain via Morocco. GPDF's capacity is about 390 Bcf/year. The newest pipeline, MEDGAZ, came online in 2011 and is owned by Sonatrach, Cepsa, Endesa, Iberdrola, and GDF Suez. It stretches 125 miles onshore and offshore, from Algeria to Spain via the Mediterranean Sea (Sonatrach, 2014a, 2014b).

These pipelines are important to both Algeria and Europe, because they transport nearly all the natural gas produced (70%), which provides about 30% of the European Union gas supply (Boukrif, 2008) shown in Fig. 1. According to the BP Statistical Review of World Energy, pipelines exports of Algerian conventional natural gas to Europe was very high, 34.8 Gm^3 in 2012, compared to that of other African countries, characterized by a total amount of only 11.0 Gm^3(Boudghene-Stambouli et al., 2012).

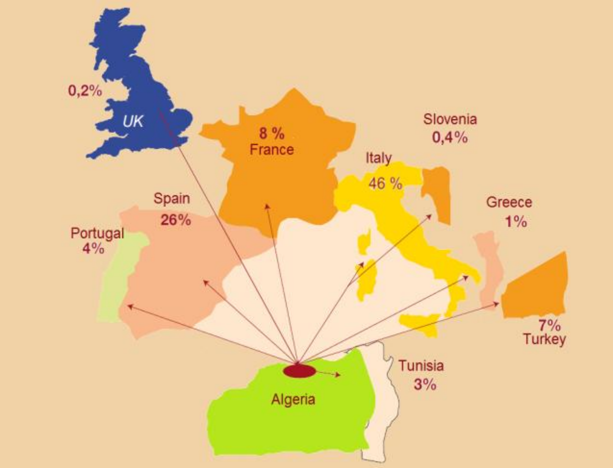

Fig. 1. Algerian exports of natural gas to Europe 2014

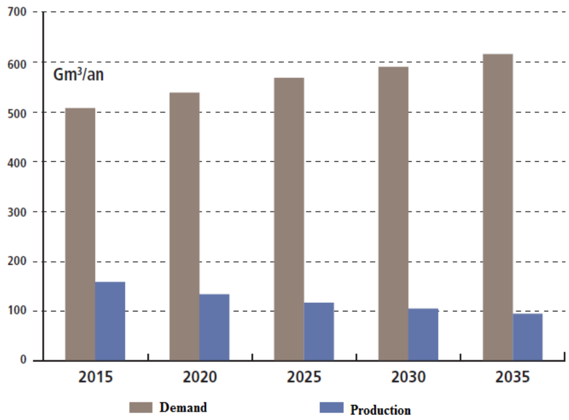

Fig. 2. Evolution of European natural gas demand and production in 2035(GRTGas, 2013)

However, in the near future, the existing export gas pipeline from Algeria to Europe will not be able to cover the increasing gas demand. In 2035, the demand for natural gas in Europe is expected to exceed 630 Gm^3 (see Fig. 2) according to the International Energy Agency; 530 Gm^3 will be imported against 331 Gm^3 in 2010. This growth was mainly driven by the gas needs natural for generating electricity (GRTgaz, 2013).

2. Backgrounds

The transmission of natural gas by pipeline is standard practice across Algeria. Natural gas is commonly transported over long distances from gas fields to customers and LNG units through a pipeline network. When the gas flows through the pipelines, it loses pressure owing to friction, and the gas is periodically recompressed in compressor stations. While there is no precise standard distance between compressor stations, they are located, on average every 100-150 km along a pipeline (Kirchgessner et al. 1997; Litto et al. 2007). These compressor stations typically contain between 1 and 15 compressors. The common types of compressors used are large slow speed reciprocating compressors driven by natural gas internal combustion (IC) engines, or centrifugal compressors powered by natural gas-fuelled turbines (Borraz-Sánchez 2010; Ríos-Mercado and Borraz-Sánchez 2015) . To get an idea of how a compressor station is structured, a plan of a compressor station is shown in Fig. 3.

Readers interested in the design and arrangement of compressor stations in natural gas transmission systems are referred to the works of Elshiekh (2015), Kurz et al. (2012), Kopanos et al. (2015), Xenos et al. (2015). Valves and regulators are typical components installed for operational and safety reasons within a pipeline system. For example, by means of a valve, gas operators can restrict or direct the gas flow from one point to another. This is rather beneficial, among other circumstances, in order to perform scheduled maintenance or to satisfy demand requirements at specific points or to prevent loss of fluid by completely shutting down the gas flow through a specific pipeline section due to malfunctions. In real-practice, regulatory requirements force the transporter to install mainline block valves at certain fixed spacing along the transmission line.

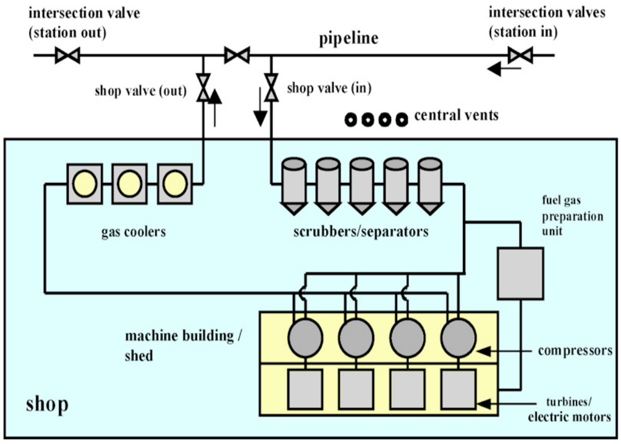

Fig. 3. Compressor station (Lechtenböhmer et al. 2007)

Methane emissions in the natural gas transmission include leaks in natural gas pipelines and compressor stations can be grouped into three sources; ❶ Combustion emissions;❷ Fugitive emissions; and ❸ Vented emissions. The first is emissions of methane resulting from incomplete combustion in the engine such as compressor engines, burners, and flares. The second source of emissions is fugitive emissions; these emissions are unintentional leaks emitted from sealed surfaces, such as packings and gaskets, or leaks from underground pipelines resulting from corrosion or faulty connections. Whilst the third is vented emissions am releases to the atmosphere by design or operational practice. Examples of vented emissions include: emissions from continuous process vents, such as dehydrator reboiler vents; maintenance practices, such as blowdowns; and small individual sources, such as gas-operated pneumatic device vents (Kirchgessner et al. 1997; Litto et al. 2007).

Causes of methane emissions are classified in different ways. Causes identified were: ❶ Start-up; ❷Normal operation; ❸Maintenance; ❹Upsets, and ❺ Mishaps.

Start-up operations, such as purging a newly constructed plant or pipeline, can involve purging natural gas directly to the atmosphere. Emissions associated with normal operation include emissions from process vents, fugitive emissions from packed or sealed surfaces or underground pipeline leaks, and emissions from gas-operated pneumatic devices. Maintenance operations involve blowing down equipment such as compressors, pipelines before maintenance begins (Kirchgessner et al. 1997). Process upsets usually involve releasing gas to the atmosphere or to a combustion device, such as a flare, as the result of overpressure or emergency shutdown conditions. Mishaps include accidental occurrences that result in emissions, such as third-party damage to pipelines (Kirchgessner et al. 1997).

Pipelines do not experience many of safety threats faced by other forms of freight transportation because they are mostly underground; but they go through a variety of areas and are subject to failures that occur over time such as leaks and ruptures resulting from corrosion or welding defects, damage from excavation, land movement, or incorrect operations.

Natural gas transportation is a critical element of Algerian strategy to manage GHG emissions. Strategies relying on current best practices or commercially available technologies, to avoid or reduce release of unburned gas to atmosphere during venting operations will be crucial to mitigating GHG emissions. Indeed, the reduction of pipeline emissions associated with CH_4 has thus become an issue of priority in the action plans and programs at Algerian national oil and gas company (Sonatrach). In the first place, since methane is the primary constituent of natural gas, the collection and utilization of methane provides a valuable, clean-burning energy source that improves quality of life in local communities and can generate revenue and improves living standards. Methane is both a potent GHG and has a short atmospheric lifetime; so reductions can also produce significant near-term results. In addition to all these facts, avoiding direct release of gas to atmosphere helps in reducing risks generated throughout the practice of this dangerous operation. Current practice creates an environmental Impact through the release of natural gas to atmosphere during maintenance repair since this typically requires removal of gas from the affected section of pipeline in order to ensure safe working conditions.

In recent years, Algeria has faced many problems in its gas pipeline network due to timeworn pipelines and to the obsolescence of equipment, especially for gas lines which were mainly installed between the 1961s and 2001s. For these reasons, considerable amounts of gases were vented directly to the atmosphere, causing huge disruption to meet the increasing natural gas demand, mainly by Europe. Gas venting is also responsible for greenhouse gas emissions, which contributes significantly to global warming and climate change of our planet. Algerian national oil and gas company (Sonatrach) had to improve the reliability of its natural gas transportation network; about 1210 km of pipelines (especially GZ0, GZ1, GZ2, GZ3 and GG1). Therefore, a huge rehabilitation plan of old pipelines has been prepared. The aim of this program is to comply with new regulations, enhance reliability, restore and improve the transport capacity.

3. Technologies and Practices

Natural gas companies have discovered many ways to reduce the amount of methane emissions from their systems. Table 1 outlines some of the major technologies and practices, summarizes the value of gas saved, and the expected payback period for the technologies and practices described (Ishkova et al. 2011).

TABLE I: Emission Reduction Technologies and Practices

Technology / Practice	Description	Value of gas saved	Payback (months)
Dry Seals (Replacing Wet Seals)	Centrifugal compressors have seals along their shaft to keep gas from escaping. Wet, or oil-lubricated, seals are common and by design result in methane leakages, sometimes substantial ones. Dry seals operate mechanically without seal ring lubrication, which in its turn reduces gas leakage	324 000 USD per compressor	8 to 24 months
Directed Inspection and Maintenance (DI&M)	A technique to find, quantify and reduce leaks in a facility on a planned schedule based on frequency of leaks and cost-effectiveness. Quantification of leaks allows companies to prioritize repairs and evaluate cost-effectiveness.	26 248 USD per station	Less than 12 months
Pipeline Pump-down	Instead of venting gas from a section of pipeline that is being depressurized for maintenance, this technology uses a portable compressor to pump much of the gas in an adjacent operational pipeline segment.	98 800 USD (assuming 4 pump-downs per month on 16 km segment)	2 months
Composite Wrap for Non-Leaking Pipeline Defect	Composite wrap permanently repairs non-leaking pipeline defects. It is very cost-effective because it allows for pipeline repairs during pipeline operation, so gas does not need to be vented.	5 600 USD per 8 meter pipeline segment	6 months
Low-Bleed Pneumatics	Gas-operated pneumatic devices such as controllers vent methane by design. Because of the large number of pneumatic devices at compressor stations, the total emissions from such devices can be substantial at a facility. Low-bleed pneumatics can significantly reduce these leaks, through either replacement of high bleed devices with low bleeds or retrofitting existing high-bleed devices.	675 USD to 1 850 USD	6-18 months

4. METHODOLOGY

Pipeline pump-down allows gas pipeline operators to reduce vented methane emissions when they take a section of pipeline offline for repairs. Normally, for safety reasons, the operator must vent the gas before repair work begins. This can involve the loss of substantial volumes of gas and money, as well as significant emissions of methane. Instead, with pipeline pump-down, the operator can use either a portable compressor, in combination with the in-line compressors, to move the majority of the gas to the next pipeline segment before depressurization.

Fig. 4 illustrates the basic sequence of events for depressurizing a pipeline segment.

We can realize significant environmental and economic benefits by using downstream in-line compressors that may or may not be combined with portable compressors to lower gas-line pressure before performing maintenance and repair activities. Potential savings include:

- Significant reduction of fire/explosion risk of vented gas
- Recovery and sale of natural gas that would have been vented to the atmosphere
- Reduction of methane emissions.
- Reduction of nuisance (noise).

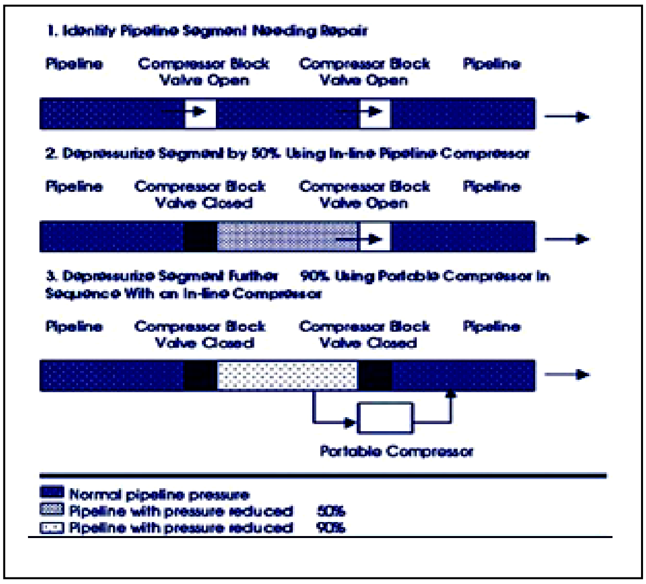

Fig. 4. Sequence of depressurizations events (US EPA 2006)

5. RESULTS AND DISCUSSION

For our calculations, we take gas pipeline **GZ3** as an example; **GZ3** has maximum allowable operating pressure of 69.09 atmospheres (atm) and 20 kilometers (km) distance between block valves. This pipeline has been chosen because it is the most leaking in the Algerian pipeline transportation network and it is concerned with rehabilitation program.

The Volume (Mcf) and value (USD) of the gas recovering from using in-line compressor and portable compressor are computed by the following equations:

$$V = \frac{\Pi D^2 L}{4RT}(P_i - P_f)MV_{ideal\ gas} \quad (1)$$

$$Ni = V - (V/R_i) \quad (2)$$

$$Vi = Ni \times 6\ \text{USD/MMBtu} \quad (3)$$

$$Np = Ni - (Ni/Rp) \quad (4)$$

$$V_g = N_p \times 6\ \text{USD/MMBtu} \quad (5)$$

$$Nt = Ni + Np \quad (6)$$

$$Vt = V_i + V_g \quad (7)$$

Where:
V: Total amount of gas in the pipeline segment (m^3)
L: Pipeline length between block valves, (meter); 20 x 10^3 m
D: GZ3 pipeline interior diameter, (meter); 1.06 m
P_i :GZ3 initial pipeline segment pressure, (atm); 63.168 atm
P_f :GZ3 final pipeline segment pressure, (atm); 1 atm
R: Gas constant R= 0.082 L.atm/mole.K
T: Gas absolute temperature in pipeline segment, (Kelvin); 294.25 °K
$MV_{ideal\ gas}$: Molar volume of ideal gas, 22.4 x10^{-3} m^3/mole
Ni : volume of gas recovered using an in-line compressor
Ri is in-line compressor compression ratio
Vi: Value of gas recovered using an in-line compressor
Np: volume of gas recovered using a portable compressor
R_p is the portable compressor compression ratio
Vg: Value of gas recovered using a portable compressor
Nt: Total gas recoverable with inline compressor and gas recoverable with portable compressor
Vt: Total value of the recovered gas from (in-line compressor and portable compressor
Gas price EU August 2017 is approximately 6 USD/MMBtu (Gas price source: Sonatrach-Trading activity)

With conversion factors:
1 Km = 10^3 m
1 inch = 2.54 x 10^{-2}m (GZ3 is 42 inch)
° Kelvin = °Celsius + 273.15 (temperature in pipeline segment, assumed 21.1°C
1litre = 10^{-3} m^3 ($MV_{ideal\ gas}$=22.4 litres/mole)
1m^3 = 35.32 ft^3 and 1 Mcf = 10^3 ft^3
1 Mcf = 1 MMBtu

From these calculations, we can obtain that a total net value of **194 161.08 USD** can be achieved by recovering about **0.916 million m^3** of natural gas, through the use of portable compressor according to the same assumption.

Evaluate of economics of using a portable compressor in sequence with an in-line compressor are computed by the following equations:

$$Vc = Vcf + Vcl + Vcm \quad (8)$$

$$Vp = Vg - Vc \quad (9)$$

$$Vtotal = Vi + Vp \quad (10)$$

Where:
Vc : Total costs associated with a portable compressor
Vcf : Cost of fuel (fuel used by portable compressor to draw down pressure from 63.168 atm until suction lost)
Vcl : Cost of labor
Vcm : Cost of maintenance
Vp: Net value of recovered portable gas
Vg: Value of gas recovered using a portable compressor
Vtotal: Total value of recovered gas
Vi: Value of gas recovered using an in-line compressor

To calculate the cost of total investment, all expenses have to be included such as compressor purchase, freight, operating costs, etc…. The costs and gas savings from **GZ3** compressor pump-downs are summarized in Table 2**.**

Table 2: Total Investments

Equipment / Practice	Costs USD
Portable Compressor Capital Cost (69.09 atm, high flow)	3 to 6 million
Portable Compressor O&M Cost	5 000 to 30 000
Labor and Transportation Cost	5 000 to 20 000
Total investments	4 million
Total Natural Gas Savings	11.628 million

From these calculations, it is clearly seen that use of portable compressor is technically and economically a feasible activity to reduce methane emissions from high pressure pipelines. Benefits justified purchase of **4 portable compressors**. Another consideration affects the beneficial use of portable pump-down compressors.

- Additional fuel use from downstream compressors can be large
- Fuel use by portable compressor
- Extra manpower and maintenance issues
- The time variable is very important, especially if service disruptions are a potential from the line being out of service
- The extra fuel consumed by inline compression due to increased friction loss is usually the critical variable

6. Conclusion

During this study, it has been demonstrated that avoiding natural gas venting directly to atmosphere is possible for the Algerian natural gas transportation network; furthermore, considerable cost saving and environmental benefits can be derived throughout the proposition of solution never used before at Algeria. Pipeline pump-down technique with portable compressor solution helps avoiding the outdated, dangerous and environmentally harmful practices.

The use of portable compressors instead of venting will mainly allow **54.873 million m^3** gases saving, which costs about **11.628 million USD** and benefits justified purchase of **4 portable compressors.**

As a developing country, Algeria has not any commitments for reducing GHG emissions under Kyoto Protocol. However, through launching CDM projects, Algeria could benefit from green investments which will contribute to sustainable development and to some extent bring additional economic benefits through carbon credits revenues and technology transfer from industrialized countries.

This work will demonstrate that when managing a complex asset like gas transportation network, it is possible to conciliate economics with safety and environment. So, it is time to change the current practices and to take actions to avoid gas venting.

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BIOGRAPHICAL NOTES

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