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Application of PHAST software in methane emission factor for startup process of gas compressors (Case study: Iran gas transmission operation district 2)

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ABSTRACT:

Introduction: Today, due to the discussion of carbon management as well as the reduction of greenhouse gases and national and international commitments involved in this regard such as the Six Development Plan (2016-2020) and climate change convention it, is necessary to calculate and manage all industrial processes that lead to the greenhouse gases emission. Methane is the main ingredient of natural gas, which its potential for global warming is 25 times more than carbon dioxide. Approximately a third of these emissions are in the different sections of oil production and processing, transferring and storing of natural gas.
Materials and methods: The present study has been done to calculate the amount of methane emission to the atmosphere by startup of Siemens gas compressors in Iran gas transmission operation district 2. In this study, operational information of 25 Siemens gas Turbo compressors related to six gas transmission stations collected and with modeling conditions in PHAST, the amount of methane emission has been determined.
Results: According to the obtained data, in 2018 this district has released 140/870 tons of methane gas to the atmosphere due to the above-mentioned process. The methane emission factor for Type C compressor is 241/15 kg, for type D compressor is 341/35 kg and this factor for type E compressor is 375/48 kg.
Conclusion: The release rate obtained for each type of the C, D and E compressors can be used to calculate the emissions of all SIEMENS 10MV2A gas compressors of the same model in Iran.

Introduction

Climate change is caused by an increase in the concentration of greenhouse gases in the atmosphere. It is a very complex atmospheric phenomenon on a global and long-term basis and an extreme climate change will occur as global warming in the next few decades [1]. It makes some regions more humid and some areas dry, and the severity and frequency of severe events such as floods and droughts will increase. Currently, the fact that humans change the state of the earth atmosphere is clear, and this phenomenon is the motivation and focus of extensive

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activities across countries and the United Nations [2].

The direct effects of climate change on health can be attributed to increase the incidence of tropical diseases, including carrier diseases (such as malaria). Other infectious diseases (such as cholera) have also indirect effects of climate change. Direct damages can also be caused by severe changes in temperature and the prevalence of related diseases such as respiratory, cardiovascular diseases [3]. Other diseases, such as yellow fever and foot-and-mouth disease, also become more common with global warming [4]. Regarding the importance of the issue, the National Climate Change Adaptation Strategy (NSP) Program has addressed vulnerability assessment policies to climate change impacts, as well as part of the sixth development plan to identify vulnerable areas affected by the effects of severe and gradual climate change has been earmarked [5].

The International Panel on Climate Change (IPCC) in a study conducted on the basis of simulations, predicts that global temperature changes on earth's surface by the end of the 21th century will increase to 1.5 degrees than 1850. The 2 ºC limit is considered to be a risk limit in global warming. Scientists say that even if we reduce greenhouse gases emission dramatically, its effects will continue, as large parts of the climate system need hundreds of years to respond to changes. In addition, it takes decades to clear greenhouse gases emitted to the atmosphere [6].

According to studies, Canada in 2014 had 534,000 tons of carbon dioxide equivalent emission in the form of vent and escape from gas transmission stations [7]. Also, according to the US Environmental Protection Agency's research (EPA), the natural gas industry transmission and storage section has accounted for 37% of the total waste gas. The largest share in all sections is dedicated to production, processing, transmission and distribution [8].

In a study conducted by the Department of Atmospheric Program in climate change section, the amount of emissions in the U.S gas transmission section in 2014 was estimated about 22 million tons of carbon dioxide equivalent, of which 2 million tons of carbon dioxide is due to the emission of methane from gas compressors [9]. Also, in studies carried out by the EPA in 2011, it was found that with the change in the design of the blow down system and shutdown management of compressors at gas stations, the amount of methane emission could be reduced to 60 million cubic meters per year [10].

Gas transmission operation district 2 has different compressor types with different manufacturers, and in each station according to conditions of the gas transmission line has been used from an appropriate compressor that was available at the time the station was established. This gas transmission operation district has 17 active gas pressure boost stations and has a total of 74 turbo compressors active in its stations. Gas compressors in this district have different manufacturers such as Summy, Nuovo Pignono, Siemens, Nevsky [11].

A total of 25 Siemens gas compressors have been used at different stations in district 2, which is more than of the other types of gas compressors in this district, and furthermore, given that the most of these compressors are located on 3th and 4th gas pipelines and operational maneuvers on these gas transmission lines are more than the other lines, so the highest number of startup is due to this type of compressors. As a result, in terms of the volume of methane emitted to the atmosphere in the process of startup, these compressors are more than the other types of compressors in district 2.

With regard to the goal of reducing 10% of the emissions during the six[th] development plan (2016-2020) [12] and the high share of gas vent in the gas transmission company, any prevention of gas losses at the booster station will have a significant effect [13, 14]. Therefore, accurate calculation of methane emission in different parts of gas stations is important. In this study, the amount of emission was computed from Siemens gas compressors, then the PHAST 7.11 was used for modeling. This software is based on the most practical and reliable software for calculating and modeling of emission and distribution of gases in the world's oil and gas industry.

Materials and methods

In order to implement the present study, a framework consists of 5 stages according to the type of compressor and operating conditions was developed.

Data collection

All Siemens gas compressors in district 2 are two stage centrifuge known as the SIEMENS 10 MV2A. This compressor model has different types, three types of C, D and E are used in this district stations. The number of startup of Siemens turbo-compressors in 2018 was collected in Table 1.

By observing all Siemens stations of district 2 the documents related to the startup of the compressors of each station were identified, considering that the same type of compressors were designed and manufactured in exactly the same way and in terms of operating conditions they installed in the same gas pipelines in same operating parameters operates the same [15], so all compressors of the same type have the same emissions. Siemens compressors at station are grouped as the Table 2.

Table1. The number of startup of Siemens turbo-compressors in 2018

Row	Name of the facility	Turbo compressor number	Total startup number
1	S1	1	8
2		2	11
3		3	14
4		4	10
5	S2	1	19
6		2	9
7		3	33
8		4	15
9	S3	1	11
10		2	13
11		3	16
12		4	9
13	S4	1	37
14		2	20
15		3	40
16		4	19
17		5	34
18	S5	1	29
19		2	18
20		3	9
21		4	13
22	S6	1	12
23		2	17
24		3	19
25		4	12
Total		25 devices	447

Table 2. Grouping of Siemens 10MV2A compressors at stations

Row	Compressor type	Name of the facility	Name of main pipelines	Number of units
1	C	S1	3	4
		S2	3	4
		S3	3	4
2	D	S5	4	4
		S6	4	4
3	E	S4	2 and 3	5

Reviewing how to emit during the startup process

At the time of startup of Siemens gas compressors, there should be no air present in the compressor booster and the line leading to it, before pressurized. Therefore, purge operation is required before the unit be set up. To do this, through a 2 inches bypass inlet valve, the gas is injected into the compressor booster and the line connected to it, and blows down from the Vent line at the outlet of the compressor into the atmosphere.

Scenario selection

In order to interpret the obtained results, data related to each type of Siemens gas compressors in gas transmission operation district 2 were loaded in the software according to the operational parameters to design and by selecting the appropriate scenario, the results were obtained from the software and were analyzed. Also in order to simulate gas emission in the process of startup of the compressor in the software, the "pressure vessel" and "short pipe" scenario were used. Therefore the software considers the compressor and the pipeline under pressure lines as a pressure vessel (tank under pressure), as well as by the short pipe scenario (short pipe), blow down from a pipe connected is simulated in a state in which rate of blow down is constant and it rate does not reduce the pressure of the tank.

Receiving report from the software

After entering the data for each type of the compressor, the output of the software will be extracted from the reports section in according to the specifications and operational conditions. For example, the results of Type E Siemens gas compressors are shown in Fig. 1.

How to calculate?

To calculate the emission in the startup process, the results in Fig. 1 (for Type E compressor) and Eq. 1 were used.

$$\mathbf{M}_{CH_4\text{Start}} = \mathbf{m}_{\text{natural gas}} . t . \%\mathbf{CH}_4 \qquad (1)$$

$\mathbf{M}_{CH_4\text{Start}}$ **:** Mass of methane released at one startup (kg)

$\mathbf{m}_{\text{natural gas}}$ **:** Mass flow rate of gas output (Kg/s)

t **:** Gas blow down time **(s)**

%CH_4: Percentage of methane in natural gas composition

The total amount of methane emission in process of startup of each type of Siemens gas compressor calculated by Tables 1, 2 and Eq. 2.

$$\mathbf{m}_{CH4/\text{year }2018\text{ start}} = \mathbf{m}_{CH4\text{ Start}} . \mathbf{N} \qquad (2)$$

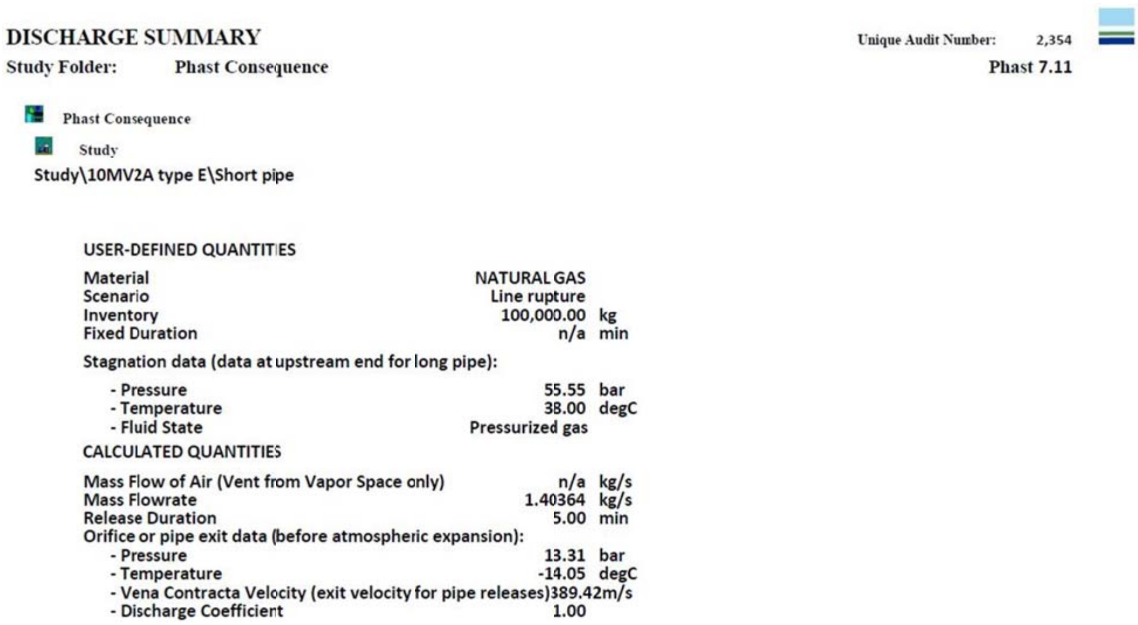
$\mathbf{m}_{CH4/\text{year }2018\text{ start}}$ **:** Total amount of methane emission in startup process in 2018 (kg)

$\mathbf{m}_{CH4\text{ Start}}$ **:** Mass of methane released at one startup (kg)

N: Number of startup in 2018

Results and discussion

According to the calculations, the amount of methane emission in all three types of Siemens gas compressor in startup process as well as the total emission from this process is presented in Table 3.


DISCHARGE SUMMARY
Study Folder: Phast Consequence
Unique Audit Number: 2,354
Phast 7.11

Phast Consequence
Study
Study\10MV2A type E\Short pipe

USER-DEFINED QUANTITIES

Material	NATURAL GAS	
Scenario	Line rupture	
Inventory	100,000.00	kg
Fixed Duration	n/a	min
Stagnation data (data at upstream end for long pipe):		
- Pressure	55.55	bar
- Temperature	38.00	degC
- Fluid State	Pressurized gas	

CALCULATED QUANTITIES

Mass Flow of Air (Vent from Vapor Space only)	n/a	kg/s
Mass Flowrate	1.40364	kg/s
Release Duration	5.00	min
Orifice or pipe exit data (before atmospheric expansion):		
- Pressure	13.31	bar
- Temperature	-14.05	degC
- Vena Contracta Velocity (exit velocity for pipe releases)	389.42	m/s
- Discharge Coefficient	1.00	

Fig. 1. Extraction of software results for the startup mode (Type E compressor)

Table 3.The amount of methane emission in startup process of Siemens gas compressors in 2018

Row	Compressor type	Startup (kg)	Total emission (ton)	CO_2 equivalent of total emission (ton)
1	C	40514	140/870	3521/75
2	D	44034		
3	E	56322		

According to the obtained results, the highest share of emission among different types of Siemens compressor is related to type E, although the lowest number of compressor (5 devices) is of this type. This high emission is due to the following reasons:

- High numbers of startup: in 2018, these types of compressors have a total of 150 startups, which is equivalent to 30 times of startup for each unit. While the type C compressors, which are 12 units, have 168 times startup, which means an average of 14 times startup for each unit.
- Another reason is the high volume of the booster and the input and output lines of this type of compressor. In C and D types, the diameter of the lines connected to compressor is 30 inches and in type E is 36 inches.

According to above discussion, the effect of the number of startup is quite clear on the emission of the gas compressors. To reduce emission, as much as possible and in according to the conditions of operation, the compressors must not be shut down and restarted in cases where it is less urgent.

Conclusion

In this study, the methane emission factor in startup process of different gas compressors in district 2 was investigated. The methane emission factor for Type C compressor is 241/15kg and methane emission factor the Type D compressor is 341/35 kg and this factor for Type E compressor is 375/48 kg .

With these emission factors and the number of startup of Siemens gas compressors in district 2, it is possible to determine the amount of methane emission for each type of compressors.

Considering that these types of compressors are used in gas transmission lines all over Iran, the methane emission factors obtained in this study can also be used to calculate the amount of methane emission in the Siemens gas compressor in other parts of the country.

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Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

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Ethical consideration

Authors are aware of, and have complied with, best practices in ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that the submitted work is original and has not been published elsewhere in any language.

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