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Estimate of Methane Emission in Startup and Shutdown Process of Siemens Gas Compressors Using PHAST Software

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Abstract

Methane is the main component of natural gases which has a potential for global warming of more than 25 times that of Carbon dioxide. Methane is the second greenhouse gas to be released by human activities, and almost a third of these emissions are in different sections of oil production and processing, transfer and storage of natural gas. The purpose of this study is to estimate the amount of Methane emission to the atmosphere due to the startup and shutdown of Siemens gas compressors in Gas Transmission Operation District No. 2. For the present study, first the total number of Siemens compressors, model and type of each compressor in District No. 2 were determined. Then the similar compressors were placed in the same group and for each group the compressor information of one station was collected as a pilot and transferred to the PHAST software, and the modeling and outputs were received and recorded. The amount of Methane emission in year 2017 in the process of startup and shutdown of Siemens compressors was found as below: type C compressors the amount of 202814 kg, type D compressors 183841 kg, and type E compressors 227098 kg of Methane emission to the atmosphere. According to the obtained information, it can be concluded that in 2017, this gas transmission District has released a total of 613.753 tons of Methane gas from the above-mentioned process in the atmosphere, which has a global warming potential of 15343.825 tons of Carbon dioxide equivalent.

Keywords: Methane emission, Gas compressors, Global warming, PHAST software, Greenhouse gases.

1 Introduction

Climate change is caused by an increase in the concentration of the greenhouse gases in the atmosphere. It is a very complex atmospheric phenomenon on a global and long- term basis. Climate change will take place in the next few decades as a global warming [1]. It makes some regions more humid and some areas dry up, and the severity and frequency of extreme events such as floods and droughts will increase. Nowadays, the fact that humans change the state of the Earth's atmosphere is clear, and this phenomenon is the motivation and focus of extensive activities across countries and the United Nations [2].

The direct effects of climate change on health can be seen in increasing the incidence of tropical diseases, including carrier disease (such as malaria). Other infectious diseases (such as cholera) are also indirect effects of climate change. Direct damage can also be caused by extreme changes in temperature and the incidence of related diseases, such as respiratory and cardiovascular disease [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 in the National Climate Change Adaptation Strategy (NSP) program, healthy policy vulnerability assessment has been addressed to climate change impacts, as well as part of the Sixth Development Plan is also dedicated to identifying vulnerable areas affected by the effect of extreme and gradual climate change [5].

The Intergovernmental Panel on Climate Change (IPCC) in a study conducted on the basis of simulations predict that global temperature changes on Earth's surface will increase to 1.5 degrees by the end of 21 century 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 emission from the atmosphere [6].

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According to studies conducted, in 2014, Canada had 534,000 tons of carbon dioxide equivalent emission in the form of Vent and Escape From gases 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, with the largest share in all sections (production, processing, transmission and distribution [8].

In a study conducted by the Department of Atmospheric Program in climate change section, the amount of emission in U.S Gas Transmission section in 2014 was estimated about 22million 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 the compressors at gas stations, the amount of Methane emissions could be reduced to 1,800 million cubic feet per year [10].

Gas Transmission Operation District No. 2 has different compressor types with different manufacturers, and in each station according to the 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.

A total of 25 Siemens gas compressors have been used at different stations of District 2, which is more than the other types of gas compressors in this district, and furthermore, given that the most of these compressors are located on third and fourth gas pipelines and operating maneuvers on these gas transmission lines are more than the other lines, so the highest startup and shutdown rates related to this type of compressors. As a result the amount of Methane emission to the atmosphere in the process of startup and shutdown of these compressors are more than the other types of compressors in the District No. 2.

With regard to the goal of reducing 10% of the emissions during the Sixth Development Plan (2016-2020) 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 [11]. 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, and for modeling the software PHAST 7.11 was used. 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.

2 Methodology

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

2.1 Data collection

All Siemens gas compressors in District No. 2 is a two-stage centrifuge, known as the SIEMENS 10MV2A. This compressor model has several types that three types of C, D and E are used in this district. The number of startup and shutdown of Siemens turbo-compressors in 2017 is summarized in Table 1.

By visiting all Siemens stations of District No. 2, the documents related to the startup and shutdown 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 operating parameters operate the same, so all compressors of the same type have the same emission. Siemens compressors at station are grouped in the Table 2.

2.2 Reviewing How to Emit During the Process

In order to review the process and operational procedures for startup and shutdown of Siemens gas compressors, first it is necessary to be familiarize with the method of connecting the lines and the position of the relevant valves. When the compressor is in operation service the gas cleaned by the scrubbers enters the entrance line through the inlet valve and from there enter the gas compressor booster. In the booster, the pressure of the gas increases in two steps and then enters to the compressor exit line, then through the outlet valve to the gas coolers. The full description of how the compressor emit in startup and shutdown process is explained in the following.

2.2.1 Start-up process

At the time of startup of Siemens gas compressors, no air should be present in the compressor boosters and the lines leading to it before pressurized. Therefore, prior to launching the unit, purge operations must be performed. To do this, through a 2-inch bypass inlet valve, the gas is injected into the compressor booster and the lines connected to it, and blow down from the Vent line at the outlet of the compressor into the atmosphere.

2.2.2 Shutdown process

By issuing a shutdown command for the Siemens turbo-compressor, the rotation of the shaft is reduced to a minimum, first. By approaching the work point to the surge-line, the unit anti- surge valve starts opening as a percentage by reaching the unit round to the ideal (5390 rpm) the valve of the anti- surge will be open completely. For about 4 minutes, the unit remains in the ideal round, then the flame is turned off and the close command issued for the inlet and outlet valves of the unit and the isolation valve of the anti-surge line and simultaneously the unit round is reduced again and the rotation of the gas compressor stops. . After this step and after about 25 minutes, while all the valves are closed, the gas contained in the compressor booster and the lines connected to it for some reasons, including safety issues through the 2-inch Vent line blow down to the atmosphere.

Table 1: The number of startup and shutdown of Siemens turbo-compressors in 2017

Row	Name of the facility	Manufacturer /builder	Turbo Compressor Number	Total startup Number	Emergency shutdown number	Number of normal shutdown
1	G3	SIEMRNS	1	13	3	10
2		SIEMRNS	2	10	2	8
3		SIEMRNS	3	16	2	14
4		SIEMRNS	4	12	0	12
5	H3	SIEMRNS	1	23	1	22
6		SIEMRNS	2	10	1	9
7		SIEMRNS	3	34	2	32
8		SIEMRNS	4	14	4	10
9	J3	SIEMRNS	1	14	1	13
10		SIEMRNS	2	12	1	11
11		SIEMRNS	3	19	1	18
12		SIEMRNS	4	8	1	7
13	K3	SIEMRNS	1	40	4	36
14		SIEMRNS	2	19	2	17
15		SIEMRNS	3	39	2	37
16		SIEMRNS	4	20	2	18
17		SIEMRNS	5	36	4	32
18	K4	SIEMRNS	1	33	1	32
19		SIEMRNS	2	20	2	18
20		SIEMRNS	3	8	2	6
21		SIEMRNS	4	16	1	15
22	L4	SIEMRNS	1	11	1	10
23		SIEMRNS	2	20	1	19
24		SIEMRNS	3	18	1	17
25		SIEMRNS	4	14	0	14
TOTAL			25 devices	479	42	437

Table 2: Grouping of Siemens compressors at stations

Row	Compressor type	Name of the facility	Compressor manufacturer	Model	Main Pipeline Name	Number of units
1	C	G3	SIEMRNS	10MV2A	Third	4
		H3	SIEMRNS	10MV2A	Third	4
		J3	SIEMRNS	10MV2A	Third	4
2	D	K4	SIEMRNS	10MV2A	The Fourth	4
		L4	SIEMRNS	10MV2A	The Fourth	4
3	E	K3	SIEMRNS	10MV2A	Second and third	5

2.3 Scenario selection

To interpret the results, the data for each type of Siemens gas compressors in Gas Transfer Operations District No.2, according to the operational parameters and design, were loaded in the software and by selecting appropriate scenario; the results were obtained from the software.

To simulate the gas emission in the process of startup of the compressor in the software, the "Pressure vessel" and the "Short pipe" scenario were used and to simulate the compressor shutdown process, the "Pressure vessel" and "Time varying short pipe release" scenario were used. Therefore the software considers the compressor and pressure pipelines as a pressure vessel. Also, with the Short pipeline scenario, blowing down from a pipe connected to the tank is simulated in a state in which rate of blow down is constant and it rate does not reduce the pressure of the tank. In the process of startup of the gas compressor, the compressor purge operation is carried out through a 2-inch pipe connected to the input header of the units, and because the header is connected to the main pipeline, this amount of blow down rate does not have any effect on the main header pressure. But in the process of shutdown of the compressor, which emission is due to the blow down of the compressor booster and the lines connected to it, the rate of blow down varies from the unit vent and, as time passes, the rates of blow down decreases and this effect also affects the tank pressure. To simulate such cases, the software uses a Time-varying short pipe release scenario.

2.4 Receiving reports from the software

After entering the data for each type of compressor, in according to the specifications and operating conditions, the output of the software is extracted from the Reports section. For example, the results of the Type C Siemens compressors are shown in Figures 1 and 2.

DISCHARGE SUMMARY Unique Audit Number: 3,019

Study Folder: Phast Consequence Phast 7.11

Phast Consequence

Study

Study\10MV2A type C\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	1.50248	kg/s
Release Duration	3.00	min
Orifice or pipe exit data (before atmospheric expansion):		
- Pressure	14.25	bar
- Temperature	-13.11	degC
- Vena Contracta Velocity (exit velocity for pipe releases)	389.76	m/s
- Discharge Coefficient	1.00	

Figure 1: Extraction of software results for startup mode (Type C compressor)

DETAILED TIME-VARYING DISCHARGE Unique Audit Number: 1,911

Study Folder: PhastConsequence Phast 7.11

PhastConsequence

Study

Study\10MV2A type C\Time varying short pipe release

Mass Flow Rate kg/s	Liquid Fraction fraction	Droplet Diameter um	Discharge Velocity m/s	Choke Pressure bar	Choke Temperature degC	Discharge Coefficient	Time min	Mass Remaining kg
7.27	0.00	0.00	391.20	16.38	-11.00	1.00	0	1,015
7.12	0.00	0.00	390.97	16.06	-11.32	1.00	0	1,009
6.99	0.00	0.00	390.76	15.76	-11.61	1.00	0	996
6.69	0.00	0.00	388.37	14.99	-14.87	1.00	0	954
6.38	0.00	0.00	385.87	14.22	-18.26	1.00	0	849
6.08	0.00	0.00	383.26	13.45	-21.79	1.00	1	774
5.77	0.00	0.00	380.51	12.67	-25.48	1.00	1	698
5.46	0.00	0.00	377.62	11.90	-29.34	1.00	1	621
5.15	0.00	0.00	374.55	11.13	-30.41	1.00	1	542
4.83	0.00	0.00	371.30	10.36	-32.69	1.00	2	521
4.51	0.00	0.00	367.83	9.58	-35.23	1.00	2	479
4.19	0.00	0.00	364.10	8.81	-38.05	1.00	2	455
3.86	0.00	0.00	360.08	8.03	-42.20	1.00	2	409
3.53	0.00	0.00	355.71	7.26	-47.74	1.00	3	384
3.20	0.00	0.00	350.91	6.49	-53.75	1.00	3	349
2.86	0.00	0.00	345.59	5.71	-56.33	1.00	4	315
2.52	0.00	0.00	339.62	4.93	-59.61	1.00	4	298
2.16	0.00	0.00	332.81	4.16	-62.82	1.00	5	264
1.80	0.00	0.00	324.87	3.38	-65.27	1.00	6	236
1.43	0.00	0.00	315.20	2.60	-68.51	1.00	7	198
1.05	0.00	0.00	301.88	1.83	-72.47	1.00	9	123
0.65	0.00	0.00	290.96	1.51	-74.25	1.00	12	96
0.00	0.00	0.00	0.00	0.00	0.00	1.00	20	56

Figure 2: Extraction of software results for shutdown mode (Type C compressor)

2.5 How to calculate

2.5.1 Startup mode

To calculate the emission in the startup process, the results in Figure 1 (Type C compressor) and Equation

$\mathbf{m}_{CH_4 start} = \dot{\mathbf{m}}_{\text{NATURAL GAS}} . \boldsymbol{t} . \%\boldsymbol{CH_4}$ Eq. (1-2)

$\mathbf{m}_{CH_4 start}$: Mass of Methane released at one startup (kg)

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

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

$\%\boldsymbol{CH_4}$ **:** Percentage of Methane in natural gas composition:

The total amount of Methane emission in the process of startup of each type of Siemens gas compressor calculated by equation 2-2 and tables 1 and 2:

$\mathbf{m}_{CH4/year_{2017} start} = \mathbf{m}_{CH_4 start} . \boldsymbol{N}$ Eq. (2-2)

$\mathbf{m}_{CH4/year_{2017} start}$ **:** Total amount of Methane emission in startup process in 2017 (kg)

$\mathbf{m}_{CH_4 start}$ **:** Mass of Methane released at one startup (kg)

N: Number of startup in 2017

2.5.2 Shutdown mode

To calculate the emission in shutdown process, the results in Fig. 2 (for type C compressor) and Equation 2-3 were used.

$$\mathbf{m}_{CH_4 stop} = (\mathbf{m}_{\text{NATURAL GAS}.\boldsymbol{T}} - \mathbf{m}_{\text{NATURAL GAS}.\boldsymbol{R}}).\%\boldsymbol{CH_4} \quad \text{Equation (2-3)}$$

$\mathbf{m}_{CH_4 stop}$ **:** Mass of Methane released at one shutdown (kg)

: Total mass of natural gas in the compressor

$\mathbf{m}_{\text{NATURAL GAS}.\boldsymbol{T}}$

$\mathbf{m}_{\text{NATURAL GAS}.\boldsymbol{R}}$: The mass of the remained natural gas in the compressor

$\%\boldsymbol{CH_4}$ **:** Percentage of Methane in natural gas composition

Also, the total amount of Methane emission in the shutdown process of each type of Siemens gas compressor were calculated as follows in Table 2-4 and Tables 1 and 2:

$$\mathbf{m}_{CH4/year_{2017} stop} = \mathbf{m}_{CH_4 stop}.\boldsymbol{N}$$

Equation (4-2)

$\mathbf{m}_{CH4/year_{2017} stop}$: Total amount of Methane emission in 2017(kg)

$\mathbf{m}_{CH_4 stop}$ **:** Mass of Methane released at one shutdown (kg)

N: Number of Shutdown in 2017

3 Results

According to the calculations, the amount of Methane emission in all three types of Siemens gas compressor inShutdown and startup process, as well as the total emission from this process in12017, is presented in Table 3.

Table3: The amount of Methane emission in startup and shutdown process of the Siemens compressors in 2017

Row	Compressor type	Startup(kg)	Shutdown (kg)	Total (kg)	Total emission (T)	CO_2 Equivalent of total emission (T)
1	C	44614	158200	202814	613/753	15343/825
2	D	47789	136052	183841		
3	E	57824	169274	227098		

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

• Number of startup and shutdown: In 2017, these types of compressors have a total of 154 startups and shutdowns, which is equivalent to 30.8 times of startup and shutdown for each unit. While the type C compressors, which are12 units, have 185 times startup and shutdown, which means an average of 15.4 times startup and shutdown 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 and shutdown 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.

4 Discussion

In 2017, Dr. Erica LeDoux of the US Environmental Protection Agency (EPA), in cooperation with Williams Company, conducted a research on greenhouse gases emission from the Ojito Gas Pressure Boost Station in New Mexico. This station uses three gas compressors to increase the pressure of the pipeline. In this study, the calculation method was used to calculate Methane emission in shutdown and startup process of gas compressors using emissions coefficient. It was determined that the emission of Methane from the process of startup and shutdown of the gas compressors at this station was 32.2 tons per year [12]. For comparison, the rate of Methane emission at G3 station of Iran Gas Transmission Operation District No.2 according to our research in 2017, is equal to 55.91 tons. The main reasons for the difference are:

• The Ojito station᾿s compressors are a reciprocating, but Petaveh station's compressor are centrifugal type, that the booster of these compressors are much higher volume than reciprocating type of compressors.

•In Ojito station input and output Compressor's lines are 24 inches, but in Petaveh are 30inches.

• The Ojito station has 3 gas compressors, while the G3 station has 4 gas compressors.

In 2015, Subramanian et al. measured the Methane emissions from 45 gas compressor stations in the United States. They conducted their research with direct measurements of escape and blow down sources and divided the sites according to Methane emission, and concluded that the Methane emission level in these sites varies from 200 to 880 standard cubic feet per minute. The blow down of the compressors, leakage from isolating valves, exhaust gas combustion engines and leakage from other equipment were recognized as the main sources of emission [13]. As mentioned above, direct measurement was used in this study, but in our study, due to the lack of suitable measuring equipment, high volume of emission at blow down time, and the absence of accurate blow down time, there was no direct measurement of the rate of emission.

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