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ENVIRONMENTAL EFFECTS AND ECONOMIC STUDY ON FLARE GAS RECOVERY FOR USING AS FUEL GAS OR FEEDSTOCK

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Abstract

Flaring reduction has high priority as it meets both environmental and economic efficiency objectives. Flare Gas Recovery system (FGRs) reduce greenhouse gas emissions and air pollutant by recovering low pressure off gases that be flared. In the present study, the impact of FGRS include GHGs and Air pollutants emission for three different cases of flare gas system investigated. A feasibility study has been performed on implementing 3 FGRs, namley, A, B and C based on tree scenarios. Scenario 1 and 2 recommend the use of recovered gas as low and high pressure fuel gas respectively. In the scenario 3 the gas recoveried is injected to the feedstock line. For all scenarios (9 FGRs), a simulation has been conducted and the electrical consumption are determined. Then the quantitative values of the flare gas recovery, GHG emissions and air pollutants reduction of each case are calculated. Moreover, cost estimation for each scenario carried out based on the economic data extracted from Clean Development Mechanism projects. The results showed that the FGRs A, B and C seems to be able to provide 29, 16.7 and 5.3 MMSm^3 each year in scenario 1 respectively, while they are slightly lower for scenario 2 and 3. Implementation of FGRs for flare A, B and C in scenario 1 consumed 2252.2, 1291.8 and 415.9 MWh/y electrical energy and other scenarios consumption is higher. The net GHG emission and air pollutants reduction of FGRs A, B and C in scenario 1 is 66479, 38175, 12315 ton CO$_2$/y and 197, 113, 36 ton/y respectively. The best result of emission reduction is related to scenario 1, and scenario 3 has lowest emission reduction. Installing FGRs A, B and C with scenario 1can save about 2.4, 1.3 and 0.4 milion dollars each year for operation and the IRR index is about %45, %35, %19 respectively. The net present values of investment and the internal rate of return suggest that the use of FGRs in scenario 1 is economically suitable. FGRs A, B in scenario 2 have IRR index %35 and %26 which these amount are higher than interst rate. FGRs C in scenario 2 has IRR lower %15. The payback time is less than 6 year in both scenario 1 and 2 and the IRR for them is more than intrest rate 15 percent. The third scenario possesses minus IRR index and this scenarion rejected. Economic analysis showed that FGRs A, B in scenario 1 and FGRs A in scenario 2 are economic in every state certainly and even in the worst state the minimum IRR is higher than discount rate (%15). Application of FGRs C has some risk. Thus, all FGRs in the scenarios 1 and FGRs A and B in scenario 2 are economical and the highest emission reduction is related to scenario 1, but all FGRs in scenario 3 are not economic surely and dismissed.

Keywords: Greenhouse gases; Emission reduction; Flare Gas Recovery; Low Pressure fuel gas; Economic consideration.

1. Introduction

Nowadays the main increased greenhouse gas emissions are global warming and consequenced climate change. Greenhouse gas such as carbon dioxide, methane, nitrous oxides and fluorinated gases all help trap heat in the Earth's atmosphere as a part of the greenhouse effect [1]. Greenhouse gases from human activities are the most significant driver of observed climate change since the mid-20th century. Increases in the different greenhouse gases have other effects apart from global warming including ocean acidification, smog pollution, ozone depletion as well as changes to plant growth and nutrition levels.

The largest source of greenhouse gas emissions from human activities in the world is from burning fossil fuels. Greenhouse gas emissions from industry primarily come from burning fossil fuels for energy, as well as greenhouse gas emissions from certain chemical reactions necessary to produce goods from raw materials [2]. The flare is the most visible sign of pollution and energy waste from gas and oil refinery and petrochemical plant.

Flaring emissions also lead to warming of the earth and intensify the natural greenhouse effect on atmosphere and hence to climate changes over the coming century. Flaring of purge, waste and unwanted gases to the atmosphere is a major concern in whole petroleum industry. To enhance the implementation of environmental friendly technologies, governments have introduced various initiatives such as, emissions limits, taxes on emissions, part funding of environmental projects and more. Gas flaring, the process of burning-off associated gas from wells, hydrocarbon processing plants or refineries, either as a means of disposal or as a safety measure to relieve pressure. It is now recognized as a major environmental problem, contributing an amount of about 150 billion m^3 of natural gas is flared around the world, contaminating the environment with about 400 Mt CO_2 per year [2-3].

However, it is also the ultimate safety system on the installations. The key to a successful emissions reduction is flare gas recovery system and designing a flare system only operating in emergencies. Jou *et al.* indicated that recovering and reusing waste tail gas emitted from petrochemical industries is a great method for saving energy and reducing the environmental impacts [4]. Liu *et al.* investigated the key energy saving technologies in Chinese refineries. They implemented flare gas recovery for fluid catalytic cracking and coker processes, as large values of hot flare gas are generated in these units. Also, the liquid fuel replacing with natural gas was suggested to reduce energy consumptions [5]. Mourad *et al.* studied on burned gas recovery in order to run the petrochemical industry or, otherwise, to maintain the rate of oil production [6].

Losses from flares are the single largest loss in many industrial operations, such as oil-gas production, refinery, chemical plant, coal industry and landfills. Flaring systems can be installed on many places such as onshore and offshore platforms production fields, on transport ships and in port facilities, at storage tank farms and along distribution pipelines. Gas flaring is one of the most challenging energy and environmental problems facing the world today. This problem can be caused by a rise in CO_2, CH_4 and other greenhouse gases (GHG) emissions in the atmosphere. Because of the increasing gas prices and growing concerns about the scarcity of oil and gas resources the interest in flare gas has increased and the amounts of gas wasted have been considered. Thus saving energy and reducing emissions are become the worldwide requirement for every country. In addition, reducing flaring and increasing the utilization of fuel gas is a concrete contribution to energy efficiency and climate change mitigation [3].

Abdulrahman *et al.* analysed the importance of the flare gas recovery through the CDM (Clean Development Mechanism) recognised by KP (Kyoto Protocol) [7]. Sterk *et al.* discussed the subsidising methods granted by the single countries to encourage the local industries to improve their energy efficiency [8]. Saidi *et al.*, after a resume of the flare gas recovery advantages, highlighted three different technologies to recover the flare gas: GTL (gas-to-liquid) technology; gas turbines in order to produce electrical energy; and finally the compression method, which consists in compressing the recovered flare gas and injecting it into the fuel gas header [9]. As aforementioned, the flare gas is obtained by mixing all the gases released in the oil refinement processes, so its molecular weight is variable and it depends on the different running plants situations. After an evaluation of the pros and cons of the possible flare gas recovery technologies, Sonawat *et al.* explained how to recover the flare gas using the ejector; in their paper, they gave detailed information about the design of the recovery system [10]. As regards the liquid ring compressor, Banwarth supplied a detailed description of the design steps required for one-stage and two-stage compressor design [11].

Worldwide, final product costs of refinery operations are becoming proportionally more dependent on processing fuel costs, particularly in the current market, where reduced demand results in disruption of the optimum energy network through slack capacity. Therefore, to achieve the most cost-beneficial plant, the recovery of hydrocarbon gases discharged to the flare relief system is vital. Heaters and steam generation fuel provision by flare gas recovery leaves more in fuel processing and thus yield increment. Advantages are also obtained from reduced flaring pollution and extended tip life. The purpose of this paper is studding on the gas flaring in industry according to environmental impacts, economic and flare gas recovery. The recovery increases the refineries energy use efficiency and the recommended idea implies a strong focus on environmentally effects and could potentially have benefits in improving awareness and management of other pollutants as well.

The waste gas recovery system represents a decrease in the flaring process and most importantly a decrease in the use of fossil fuels. Consequently, the recovery reduces GHG emissions, and air pollutant, which are directly related to local air quality. This is expected to have a positive impact on the living conditions of the employees living close to the plant.

2. Environmental effect of flaring

There are many gas refineries around the world that send huge amounts of gas to the atmosphere through flaring. CO_2 emissions from flaring have high global warming potential and contribute to climate change. Flaring also has harmful effects on human health and the ecosystems. The low quality gas that is flared releases many impurities and toxic particles into the atmosphere during the flaring process. Acidic rain, caused by sulfur oxides in the atmosphere, is one of the main environmental hazards which results from this process [12].

According to research performed by the World Bank’s Global Gas Flaring Reduction Partnership (GGFR), the equivalent of almost one third of Europe’s natural gas consumption is burned in flares each year which contributes to about 400 million tons of carbon dioxide emission to the atmosphere (roughly 1.5% of the global CO_2 emissions). Pollutants discharged from flares also, include sulfur oxides (SOx), nitrogen oxides (NOx) and volatile organic components (VOC) [13]. The impacts of flare emissions therefore include the health impacts associated with exposure to these pollutants, and the ozone forming potential (and hence indirect health impacts) associated with hydrocarbon and NOx emissions, and the greenhouse gas effects of methane and CO_2 emissions.

3. Flare gas recovery system

A flare system is in general necessary for a refinery to ensure its integrity and comply with safety aspects. Flares are combustion devices designed to safely and efficiently destroy waste gases generated in a plant. In the refineries these waste gases are collected in piping headers and delivered to a flare system for safe disposal. A flare system has multiple flares to treat the various sources for waste gases [14].

The flare gas can come from exhaust of utilities, safety valves or vent connections. Gas composition depends on the equipment and utilities which are connected to the flare networks. There is in fact no standard composition and it is therefore necessary to define some group of flare gas according to the actual parameters of the gas [15]. The idea is recovering the waste gases in normal condition and putting it back into the fuel gas system or feedstock. With the help of technological advancement in this field, now we can dramatically reduce the volume of burned gases in refineries using a gas compression and recovery system. Flare gas recovery systems eliminate emissions by recovering flare gases.

Even in most advanced countries only a decade has passed from flare gas recovery technology, thus the method is a new methods for application in refineries wastes.

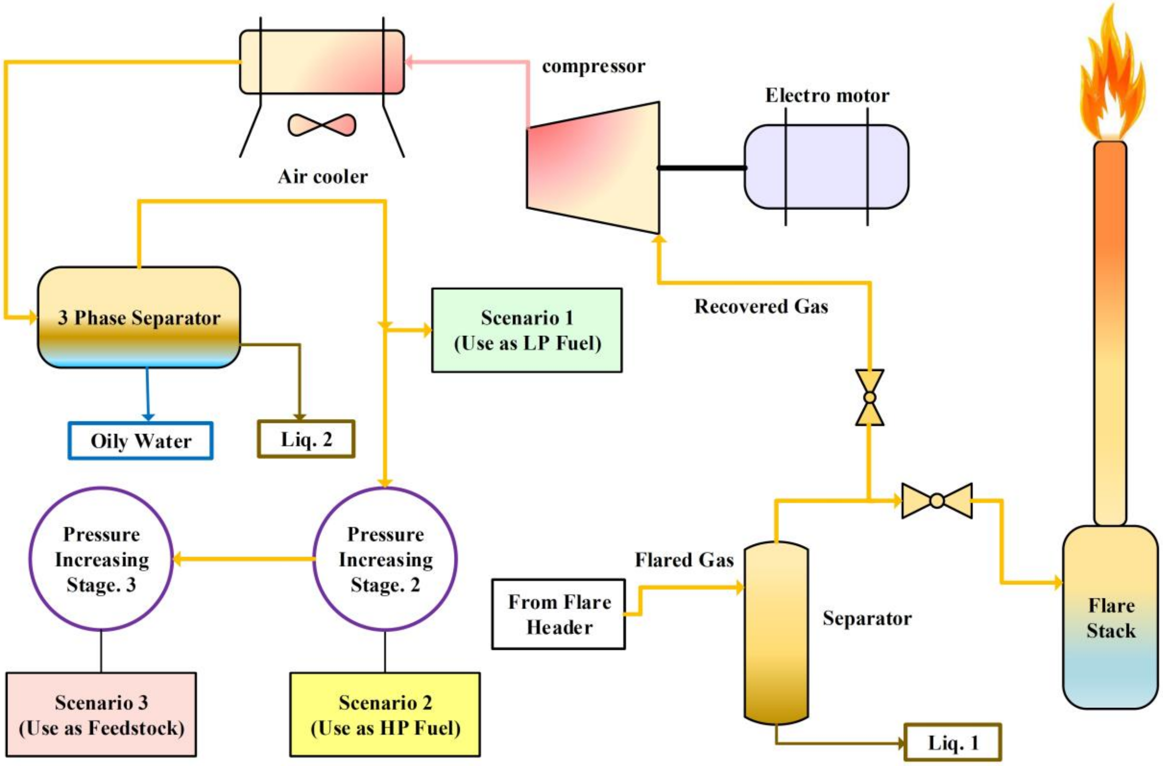

Fig. 1. Typical flare gas recovery system [8]

In this idea, according figure 1 waste gases, which are being flared prior to the implementation of the proposed idea will be recovered and used as a fuel in the fuel gas system or injected to the feedstock line. The flare gas recovery entails installation of a Flare Gas Recovery System (FGRS) in order to recover low pressure waste gas that is currently being flared. The Flare Gas Recovery System will be a skid mounted packaged unit and will be installed between flare Knock Out Drum (KOD) and Flare stack. The unit consists of compression unit, Knock out drum, Heat exchangers/cooler and PLS based instrumentation. The FGRs comprise of two trains, one of which will be working and other will be standby. The compressor will take suction from the above mentioned flare gas headers upstream of the liquid Seal Drum, compress the gas and cool it for reuse in the Refinery Fuel Gas system to be available for use as fuel in the process furnace/ burners or as feadstock.

Several compression technologies are available for FGR Systems. Proper selection of the type of com-pressor for each application is very important. Although, theoretically, any kind of compressor can be used, some kinds have earned broader acceptance in this service than others. The chosen compressor technology greatly affects the FGR System initial cost, FGR System physical size, and FGR System ope-rating and maintenance expense [15]. To compress gases and to design flare gas recovery unit, in general, liquid ring compressors or reciprocating compressors are used. Advantage of first type is that gas is cooled during compression by heat transfer of gas through water inside compressor (usually water). Reciprocating compressors are purchased easily than the first type, also spare parts provision, repair and maintenance is much easier. If using reciprocating compressors, please note that it will explode if temperature exceeds over allowable limit.

4. Combustion GHG emissions estimation

This part provides information on emissions estimation of the main greenhouse gases from combustion. Carbon dioxide, CH_4, and N_2O are produced and/or emitted as a result of combustion.

A material balance approach, based on fuel usage data and fuel carbon analyses, is the most reliable method for estimating emissions from stationary combustion sources. This approach applies to the combustion of any fuel, though fuel carbon analyses are likely more readily available for produced or purchased gas streams than for refinery gas, liquid or solid fuels. Combustion of hydrocarbons can be represented by the following general reaction, assuming complete combustion [16]:

$$C_xH_yO_z + \left(x + \frac{y}{4} - \frac{z}{2}\right) O_2 \rightarrow (x)CO_2 + \left(\frac{y}{2}\right) H_2O \tag{1}$$

Emissions of CO_2 are calculated using a mass balance approach. The equations are slightly different depending on whether the fuel combusted is a gas, liquid, or solid. For combustion of gaseous fuels, CO_2 emissions can be calculated using following equation, assuming 100% oxidation.

$$E_{CO_2} = FC \times \frac{1}{molar\ volume\ conversion} \times \mathrm{MW_{Mixture}} \times \mathrm{Wt\%C_{Mixture}} \times \frac{44}{12} \tag{2}$$

The carbon content of a fuel mixture is a weighted average of the individual component carbon contents. The carbon content of the fuel mixture can then be calculated using following equation.

$$\mathrm{Wt\%C_{Mixture}} = \frac{1}{100} \sum_{i=1}^{\#\mathrm{components}} (\mathrm{Wt\%_i} \times \mathrm{Wt\%C_i}) \tag{3}$$

Emissions of CH_4 and N_2O are calculated using emission factors [14].

5. Simulation

Flare gas recovery systems is simulated and showed in figurs 2, 3 and 4. The system is simulated steady state, and the equipment specifications, the mass balance, the energy and a schematic of the process are obtained. According to this study, the capacity of simulated FGR unit is equal to normal capacity of flaring in the a refinery (a case study).

The gas streams should reach a specified pressure (Scenario1: 7.9 bar) before introducing to the low pressure fuel gas system like as figure 2. The recovered and compressed gases are distributed to low pressure fuel consumption equipment such as furnaces and boilers. If the recovered gases are used in high pressure fuel gas system of the refinery (Scenario 2), the compressor outlet pressure is considered as 25.5 bar. The simulation plans to install 5 equipments consists a gas compressor with two stage, separator, 3-phase separator, air-cooled heat exchanger and splitter to increase the pressure of flare gases. In scenario 3 the flare gas recoveried is injected in feed stock line of refinery. In regard with the plant units, the flare gas recovery package includes one standby compressor.

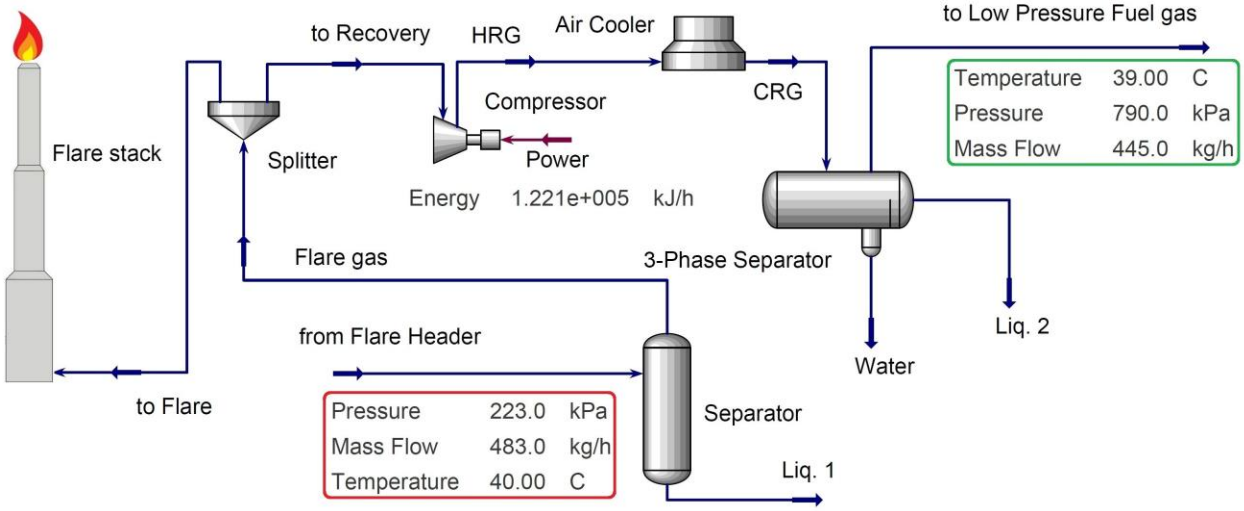

Fig. 2. A schematic of flare gas recovery system (Scenario 1)

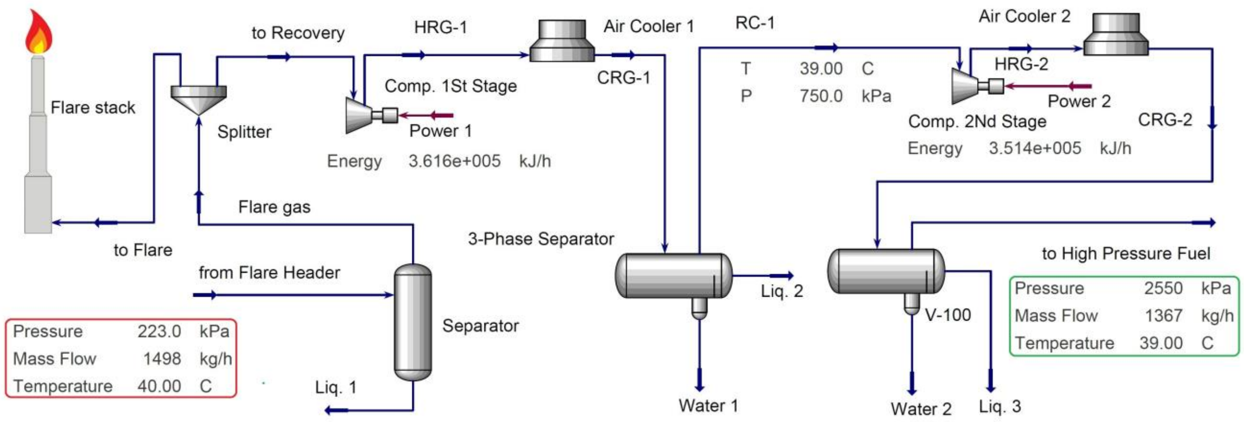

Fig. 3. A schematic of flare gas recovery system (Scenario 2)

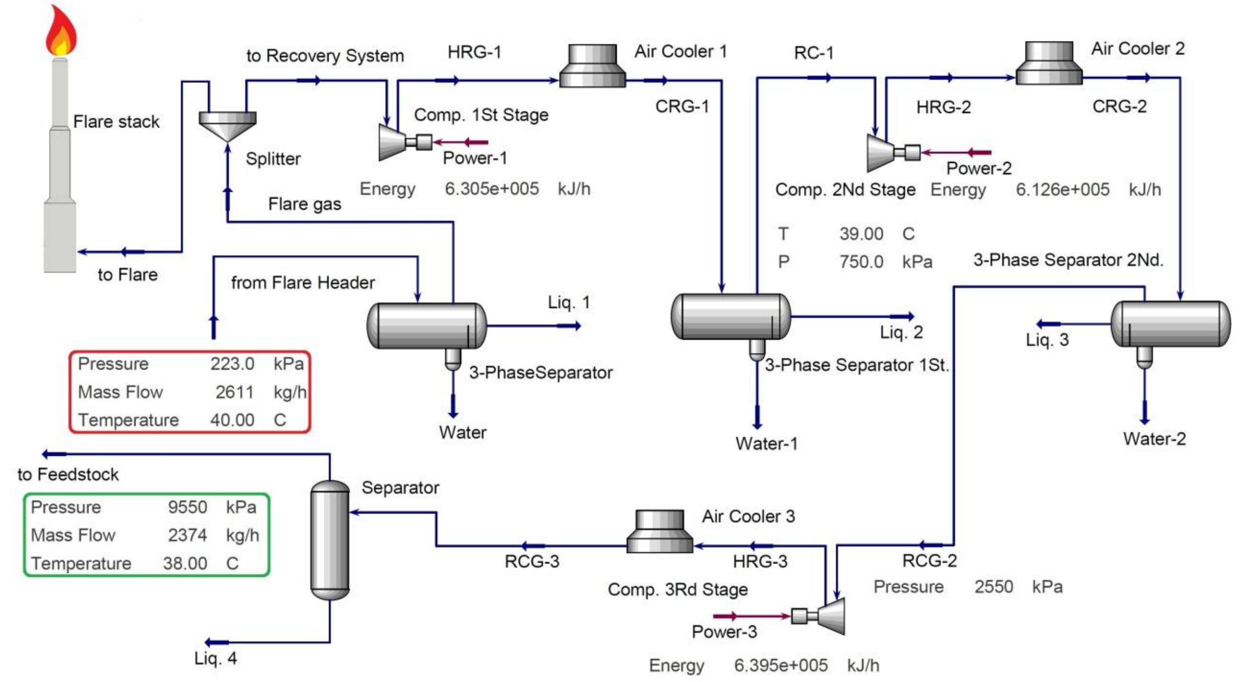

Fig. 4. A schematic of flare gas recovery system (Scenario 3)

6. Result and discussion

In this section environmental effect of electrical consumption and flare gas recovery emission reduction studied, then economic parameters evaluated and risk of each scenario is evaluated.

6.1. Electrical-specific emission factor

It is assumed that the electrical energy produced by 3 turbines (UGT-2600) that one of them is standby. The methodology for power plant-specific emission factors involves calculating the total emissions from the generation of electricity within a power plant and dividing by the total amount of electricity produced by the power plant. Based on sample operation data, average of fuel consumption and electrical energy productions in 3 years equal to 82.5 MM Nm^3 and 161732 MWh respectively and the percent of fuel gas and flare composition is mentioned in table (1).

Table 1. Fuel consumption components.

Component		Power plant fuel	Flare-1	Flare-2	Flare-3
CH_4	Methane	86.90	80.57	82.09	81.01
C_2H_6	Ethane	3.25	3.42	2.42	3.57
C_3H_8	Propane	1.18	1.27	1.03	1.19
C_4H_{10}	i-Butane	0.31	0.29	0.31	0.38
C_4H_{10}	n-Butane	0.61	0.66	0.56	0.47
C_6H_{14}	Hexane	0.19	0.09	0.1	0.07
C_7^+	Heavy C.	0.1	1.3	2.23	1.89
N_2	Nitrogen	6.21	5.75	4.93	4.87
CO_2	Carbon dioxide	0.93	0.53	0.48	0.72
H_2O	Water	0.02	6.12	5.85	5.83

Total emissions and emission factor calculated from fuel gas data components (Table 1), amount of fuel gas consumption and electricity generation in power plant by applying the mentioned methodology and presented in table (2).

Table 2. Power plant-specific emission factors

CO_2	CH_4		N_2O		Sum	NOx	CO	PM	VOCs
ton	kg	ton CO_2e	kg	ton CO_2e	ton CO_2e	ton			
164546	11680	292	4104	1223	166061	391	100.2	5.8	2.6
kg/MWh									
1017.4	72.22	1.81	25.4	7.6	1026.8	2.42	0.620	0.036	0.016

In table 2 amount of CH_4 and N_2O is reported versus CO_{2e}. Global warming potential (GWP) of each gas is used to convert the effects gases into equivalent amounts of CO_2. These ratios are based on Standard ratio, which describes its total warming impact relative to CO_2 over a set period, usually a hundred years. Over this time frame, according to the standard data , methane scores 25, nitrous oxide comes in at 298 [15].

6.2. Net emissions reduction

The real case study in this work is tree Flare Gas Recovery Systems (FGRs), specifications of them consists flow rate and FGRs electrical consumption according to simulations are showed at table 3. Data of this table showed with increase the flow rate of flare gas, the electrical consumption increased.

Table 3. Flare gas recovery systems specifications.

Item		Unit	FGRs A	FGRs A	FGRs A
Flared Gas		MM Sm^3/day	31.5	18.1	5.8
Recovered Gas	S-1		29.0	16.7	5.3
	S-2		28.7	16.5	5.2
	S-3		28.6	16.5	5.2
Electrical consumption		MJ/h	925.5	530.9	170.9
Scenario 1		MWh/y	2252.2	1291.8	415.9
Electrical consumption		MJ/h	1738.9	998.3	321.3
Scenario 2		MWh/y	4231.4	2429.0	781.9
Electrical consumption		MJ/h	2635.6	1511.7	486.6
Scenario 3		MWh/y	6413.4	3678.5	1184.1

Table 4. Greenhouse gas and air pollutant emission for each flare system and FGRs base in each scenario

Item		NOx	CO	PM	VOCs	Sum P.	CO_2	CH_4	N_2O	Sum GHG
Unit		Air pollutant (ton/y)					ton CO_2e/y			
Flare Emission (base)										
Flare 1		146.74	44	3.96	2.86	197.56	66325.27	2448.49	36.3	68809.95
Flare 2		84.26	25.3	2.31	1.65	113.52	38075.51	1405.58	20.79	39501.99
Flare 3		27.28	8.14	0.77	0.44	36.52	12282.49	453.42	6.82	12742.62
Net emission reduction= Flare emission base- Electrical consumption emission										
S. 1	F. 1	141.3	42.6	3.9	2.8	190.6	64033.9	2444.4	19.2	66497.4
	F. 2	81.1	24.5	2.3	1.6	109.5	36761.2	1403.2	11.0	38175.6
	F. 3	26.3	7.9	0.8	0.4	35.3	11859.4	452.7	3.7	12315.6
S. 2	F. 1	136.5	41.4	3.8	2.8	184.5	62020.2	2440.8	4.1	64465.1
	F. 2	78.4	23.8	2.2	1.6	106.0	35604.2	1401.2	2.3	37007.9
	F. 3	25.4	7.7	0.7	0.4	34.2	11487.0	452.0	0.9	11939.8
S. 3	F. 1	131.2	40.0	3.7	2.8	177.7	59800.3	2436.9	3.8	62224.7
	F. 2	75.4	23.0	2.2	1.6	102.1	34333.0	1398.9	2.2	35724.9
	F. 3	24.4	7.4	0.7	0.4	33.0	11077.8	451.3	0.8	11526.8

Resulted GHG and air pollutant emission of electricity consumption is evaluated by multiplying power plant-specific emission factors to the quantity of electricity consumption and the result showed in table 4. The net amount of emission reduction (Net emission reduction= Flare emission base- Electrical consumption emission) by FGRs implementation for Flare A, Flare B and Flare C is showed in table 4. The net GHG emission and air pollutant reduction of FGRs A, B and C in scenario 1 is 66497, 38175, 12315 ton CO_2/y and 190, 109, 35 ton respectively. The best result of emission reduction is related to scenario 1 and scenario 3 has lowest emission reduction.

6.3. Economic considerations

Most FGR system has been installed based primarily on economics, where the payback on the equipment was short enough to justify the capital cost. In order to draw a comparison between flare system and FGRs, the use of both operational and economical concepts should be considered; the economical parameters are calculated through the incorporation of operational results. The life time for calculation is 10 years and the total capital cost for each flare gas recovery systems are estimated from Clean Development Mechanism (CDM) projects design document [17-18]. The cost for operating and maintenance is estimated about 2 percent of capital cost, interest rate is equal to Iran's bank interest rate value which is around 15 percent, and energy price rate was estimated about 0.017 $/kWh (602 Rial/kWh in Iran).

Table 5. The economical parameters for flare gas recovery systems.

Scenario		S-1			S-2			S-3		
Item	Unit	F-A	F-B	F-C	F-A	F-B	F-C	F-A	F-B	F-C
Investment	1000$	4856	3396	1675	5796	4157	2100	41656	31895	15628
Annual C.	1000 $/y	83.2	73.9	37.5	116.0	83.2	42.0	210.9	113.4	84.4
Elec. C.		56.3	32.3	10.4	105.8	60.8	19.6	160.3	92.0	29.6
Income		2379.8	1367.4	438.2	2357.1	1354.4	434.0	2348.5	1349.5	432.4
Interest R.	%	15								
IRR		45.01	35.34	19.32	35.01	26.30	12.05	-11.6	-14.8	-21.8
NPV	$10^6$$	6387.6	2933.7	283.8	4920.6	1917.7	-231	-31.7	-25.9	-14.0
Payback	Year	2.2	2.7	4.3	2.7	3.4	5.6	21.1	26.8	49.1

The savings through each year are shown in the table 5; Just 2.4, 1.3 and 0.4 milion dollars could be saved by installing flare gas recovery systems for flare A, flare B and flare C respectively in Scenario 1. IRR index of flare A, B and C in the first and second scenario are about %45, %35, %19 and %35, %26, %12 respectively. The IRR of FGRs C in scenario 2 is %12.05 and with decreasing of the gas price or increasing of investment cost, the NPV index may is found to become negative. The third scenario possesses minus IRR index and this scenarion rejected. The payback time is less than 6 year in both scenario 1 and 2 and the internal rate of return for them is more than 15 percent whereas at the time the rate of bank interest in Iran was about 15%. Thus, the results showed that all FGRs in the scenarios 1 and FGRs A and B in scenario 2 are economical, But all FGRs in scenario 3 are not economic surely and dismissed. Estamation of finance and economics of scenarios 1 and 2 in the future is important and economic analysis help to evaluate the risky.

7. Economic analysis

Scenario analysis is a process to ascertain and analyze possible events that can take place in the future. With this tool, the actual cash flows, the intial investment and annual cost variation effect with ±%20 margin on IRR evaluated.

The expected cash flows that use to value scenario analysis can be estimated in two ways. These two ways can represent a probability of cash flows under expected or it can be the cash flows over the most likely. Also, there are other parameters like investment and annual cost where will be different from expectations; higher than expected in some and lower than expected in others. In scenario analysis, IRR estimate expected cash flows and asset value under ±%20 various, with the intent of getting a better sense of the effect of risk on value. At the worst state or IRR minimum, it is assumptions that all negative factors on attractive economy occurred simultaneously; accordingly it can be estimate IRR if everything works to perfection – a best case– and if nothing does – a worst case state. In opposite the minimum IRR, if all positive factors on attractive economy occurred the maximum IRR is achieved.

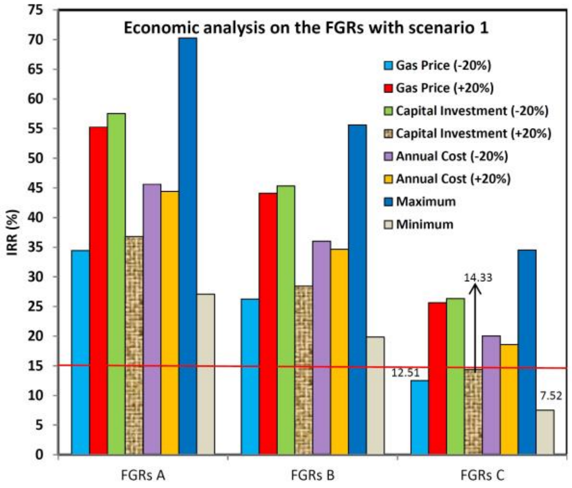

Fig. 5. Economic analysis on the FGR with scenario 1 at ±%20 variation on effectual parameters.

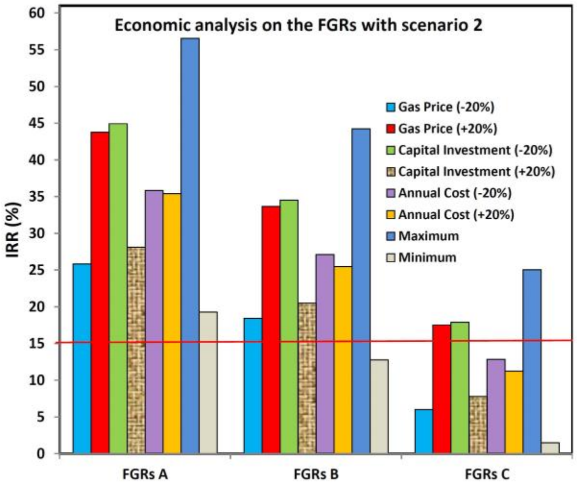

Fig. 6. Economic analysis on the FGRs A, B and C with scenario 2 at ±%20 variation on effectual parameters.

Figure 5 showed that FGRs A and B with scenario 1 are economic certainly in every state and even in the worst state (Minimum IRR), the amount of IRR is higher than interest rate (%15). Application of FGRs C has some risk and without environmental considerations, it is economic boundary condition. However the gas price increases or investment cost reduces, the IRR of FGRs C is comprative higher than interest rate. Also figure 6 showed that FGRs A with scenario 2 is economic and the risk in this scenario is zero. In application of FGRs B has a little risk, but at totally it is economic and recommended, becase only minimum IRR in this scenario is lower than %15. The economic risk of FGR C is high and it not recommended.

In terms of economical considerations, installing flare gas recovery system and used as low pressure fuel gas (Scenario 1) and high pressure fuel gas (FGRs A and B in scenario 2) is a feasible idea for GHG and air pollutant emission reduction and energy saving.

8. Conclusion

Flaring in oil and natural gas companies generate a large amount of greenhouse gases (GHGs) in almost every point of world. There is growing interest in minimizing flaring, in part due to the pollution emissions generated by flaring and potentially significant emission sources within a plant. The flaring reduction has high priority as it meets both environmental and economic efficiency objectives. Flare gas recovery system reduces greenhouse gas emissions by recovering low pressure off gases that would otherwise continue to be flared. But the FGRs compressors consumed some electrical energy, which equal of this energy consumption, GHG emission increased. The steady state simulation results indicate that if the flare gas recovery system is used, the recovery would be possible under tree scenario 1, 2 and 3 includ one, two and tree compressor stage for safe operation recpectively. Implementation flare gas recovery systems for flare A, flare B and flare C and them used as low pressure fuel gas (scenario 1) consumed 2252.2, 1291.8 and 415.9 MWh/y electrical energy. For each flare gas recovery system equal amount of recovered gas the GHG and air pollutant emission are redacted. The net GHG emission and air pollutants reduction of FGRs A, B and C in scenario 1 is 66479, 38175, 12315 ton CO_2/y and 197, 113, 36 ton respectively. The best result of emission reduction is related to scenario 1, and scenario 3 has lowest emission reduction.

Results show that installing FGRs A, B and C with scenario 1can save about 2.4, 1.3 and 0.4 milion dollars each year for real operation and the IRR index is about %45, %35, %19 respectively. The net present values of investment and the internal rate of return suggest that the use of FGRs in scenario 1 is economically suitable. FGRs A, B in scenario 2 have IRR index %35 and %26 which these amount are higher than interst rate (15%) and FGRs C in scenario 2 has IRR lower %15. The third scenario possesses minus IRR index and this scenarion rejected. The payback time is less than 6 year in both scenario 1 and 2 and the internal rate of return for them is more than 15 percent whereas at the time the rate of bank interest in Iran is about 15%.

Economic analysis showed that FGRs A and B with scenario 1 are economic in every state certainly and even in the worst state (Minimum IRR), the amount of IRR is higher than discount rate (%15). Application of FGRs C has some risk without environmental effects considerations, it is economic boundary condition. However the gas price increases or investment cost reduces, the IRR of FGRs C is comprative higher than interest rate. Thus, all FGRs in the scenarios 1 and FGRs A and B in scenario 2 are economical and the highest emission reduction is related to scenario 1, but all FGRs in scenario 3 are not economic surely and dismissed.

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