

Technical and Economic Feasibility Study of Methanol Production from Flaring Gas in Iran

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Abstract

The Increasing trend of gas flaring over oil fields and gas process systems in Iran not only causes several environmental problems, but makes the economic resources useless as well. Considering the high amount of flaring and also old facilities in oilfields in Iran, one of the best solutions is the recovery of flare gas. It seems that collecting the flare gas is not possible in different sectors. Therefore, in this paper, the feasibility study of converting flare gas to methanol in small scale is discussed. As a result, a methanol plant is simulated; whose input feed is the content of oil field flare gas of Iran (Marun and Siri). The payback period and net present value are also appraised. The payback period is evaluated around 4 years for Siri and 6 years for Marun.

Key words: flare gas; Methanol production; internal rate of return; payback period

1. Introduction

Flares are one of the vital safety and emission control devices in the oil and gas processing industry. Flaring, which combusts hydrocarbon gas streams, is necessary to prevent uncontrolled releases to the atmosphere and to relieve dangerous equipment overpressure conditions. Flaring is usually preferable, thanks to both safety and greenhouse gases emission considerations. The most recent data reported by the Energy Information Administration (EIA) indicated that approximately 3.4×10^{12} cubic feet of natural gas are flared annually, which was about 2.7 percent of all natural gas production in the world [1].

Table 1. World Bank Estimated Top Twenty Gas Flaring Countries [2,3]

Rank	Country	Flared Volume, 10^9 cubic meters 2009	Approximate CO ₂ Emissions from Flaring (10^6 tones/year) for 2006
1	Russia	46.6	116.4
2	Nigeria	14.9	46
3	Iran	10.9	28.9
4	Iraq	8.1	17.7
5	Kazakhstan	5	14.3
6	Algeria	4.9	14.8
7	USA	4	4.5
8	Saudi Arabia	3.5	7.9

9	Libya	3.5	10.3
10	Angola	3.4	9.5

As shown in table 1, the top 10 countries accounted for the flaring of 105 billion cubic meters, which is over 71 percent of the total flaring in the world in 2009. The CO₂ emissions to natural gas flaring have also shown in this table [2].

The recovery of flare gas is of importance for many advanced countries around the world due to the saving resources and reducing air pollution. There are various ways to recover flare gas. Figure 1 represents some possible strategies to recover flare gas in Iran. Statistics shows that the ratio of flare gas to oil and gas production is highly increasing in this country [4]. Moreover, it can be seen that Iran stands in the third place of top flaring countries (table 1).

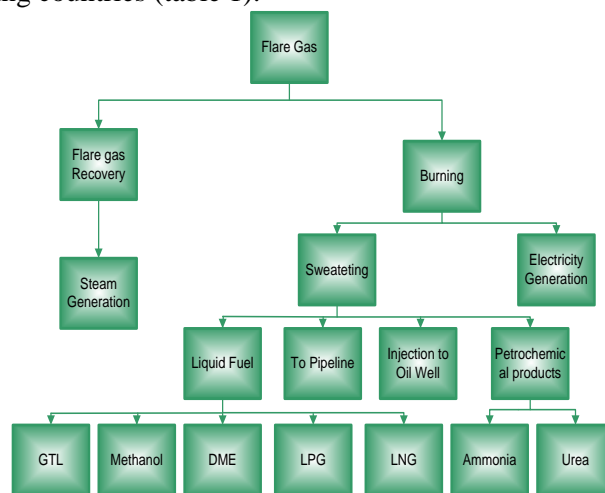


Figure 1. Possible strategies to recover flaring gas in Iran [5].

Consequently, providing the performance of Kyoto Protocol in Iran, the recovery of flare gas becomes very significant. As a result, in this paper, the feasibility study of the methanol production in small scales from the flare gas is studied. In the first section, for observing the significance of flare gas recovery, the detailed Iran's gas flaring data are presented. Then the simulation of mini methanol plant is described in the second part. In order to present the economic results for the simulated plant, we generate two scenarios, one scenario is with consideration of the environmental taxes of gas flaring and the second one is without considering them.

2. Modeling and Simulation

The process of methanol production can be divided in to three stages: synthesis gas production, methanol production; purification of methanol. Syngas production from natural gas is divided into three main categories; steam reforming, ox reforming, and CO₂ reforming. For each reaction mechanism, the enthalpy change and stoichiometric H₂/CO ratio are described in Table 2 [6].

Table 2. Reactions and Applications of Syngas

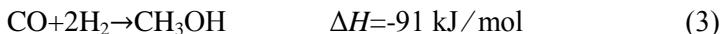
Reaction	H ₂ /CO	ΔH° (298K)	Application
$\text{CH}_4 + \text{CO}_2 \rightarrow 2\text{CO} + 2\text{H}_2$	1	206kJ/mol	Oxo alcohols
$\text{CH}_4 + 1/2\text{O}_2 \rightarrow \text{CO} + 2\text{H}_2$	2	-36kJ/mol	FT synthesis
$\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$	3	247kJ/mol	methanol synthesis
$\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$	>3	247kJ/mol	H2 production & ammonia synthesis
$\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$		-47kJ/mol	

The steam reforming process is significantly used for hydrogen and syngas production. Syngas produced from steam reforming has the high synthetic ratio (H₂/ CO) around 3 and is thus consumed by hydrogen production or ammonia synthesis processes. This method usually used for producing methanol in small scales. For methanol production, with a primary synthetic ratio equal to 2, we adjusted the synthetic ratio by lowering the hydrogen concentration through a CO₂ injection to the system [7].

For the simulating of methanol production, the flare gas as an input product must have maximum 0.25 ppmv Hydrogen sulfide [8]. The heavy hydrocarbons like propane, butane, pentane, and so forth must also be separated. Because the reforming processes of SMR (Steam reforming) are simultaneously conducted in one reactor, it has the advantage of relative compactness on size attribute and simplicity. Therefore, it is most cost-effective, and preferred, to use a steam reforming to obtain syngas [9]. Also the synthetic ratio of SMR is around 3, which cannot satisfy the requirement of syngas. Therefore, this ratio will be satisfied by the recovery of CO₂ from the purge gas of Methanol Production unit. The syngas then enters the methanol reaction. The primary reactions and simulated specifications are described below.

Where methanol synthesis is based on carbon oxides (CO and CO₂) and hydrogen, equilibrium reactions are involved that are exothermic in the direction of methanol formation as shown in equation 3 and equation 4. As the exothermic reaction proceeds with volume contraction, one obtains maximum MeOH production at low temperatures and high pressure. CO conversion of MeOH synthesis is known to be around 0.9 at 250 °C, 5000 kPa, and CO₂ conversion is 0.15 under the same conditions [10].

Methanol reaction part at 250 °C, 5000 kPa:



In the case of consuming flare gas as a main feed stock, two flare gas contents of Iran's oil fields namely Marun (from national Iranian south oilfields company) and Siri (from Iranian Offshore Oil company) is described in table 3.

Table 3. the content of flare gas

Condition	Marun	Siri
temperature °C	49	26.5
pressure (barg)	8.27	27.5
flow rate (MMSCFD)	9.228	35
content	volume percentage	volume percentage
H ₂ S	0.03	60 ppmv
Nitrogen	0.25	0.66
CO ₂	0.12	2.62
Methane	66.11	81.71
Ethane	14.76	7.73
i-Butane	1.5	.83
n-Butane	3.68	1.3
i-Pentane	1.08	.37
n-Pentane	.98	.32
C6+	.59	.19

3. Economic Analysis

Several assumptions are adopted to conduct the economic analysis and to determine the profitability of the two gas content (Marun and Siri). (1) The main lifetime of this system is supposed to be 20 years; (2) The time duration of this system is around 7200 hours per year; (3) All the data are calculated according to value of 2009; (6) The average selling price of methanol is 250\$ per ton in Middle East [11].

A summary of the economic analysis for each process is displayed in Table 4.

Table 4. capital cost of Marun and Siri's flare gas

Capital Investment Cost(US\$)	Marun	Siri
Equipment cost	10,218,802	29,962,800
Direct Costs	36,787,687	107,866,079
Purchased Equipment installation	4802836.912	14082515.85
Instrumentation and control(Installed)	3,678,769	10,786,608
Piping(installed)	6,948,785	20,374,704
Electrical systems(installed)	1124068.214	3295907.966
Building(included services)	1,839,384	5,393,304
Yard improvements	1,021,880	2,996,280
Service facilities(installed)	7,153,161	20,973,960
Indirect costs	14,715,075	43,146,432

Engineering and Supervision	3,372,205	9,887,724
Construction Expense	4,189,709	12,284,748
Legal expense	408,752	1,198,512
Contractor's fee	2,248,136	6,591,816
Contingency	4,496,273	13,183,632
Fixed Capital Investment	51,502,762	151,012,510
Working Capital	9,094,734	26,666,892
Total Capital Investment	60,597,496	177,679,402

To perform the economic evaluation, the capital cost should be estimated by Percentage of delivered-equipment cost method [12]. In this method, equipment cost was used to calculate the capital cost. The unit size of each facility could be estimated from the simulation flow rate, heat exchange area, and fluid power. The purchased cost for base conditions could be calculated from these size parameters. Related costs were calculated based on the Chemical Engineering Plant Index for 2002. The methanol cost can be calculated as table 5, when flare gas was set at a price of 0 C\$/per cubic meter and selling price for methanol set to be 250 \$ per ton.

Table 5. Methanol cost with input gas price of 0\$

cost	Marun	Siri
Direct Production Cost(US\$/yr)	8,842,628.02	25,927,686.41
Annual Output of system(Ton/yr)	100497.6	364415.256
Methanol Cost(\$/Ton)	87.99	71.15

The payback periods and also net present value of two gas input of Marun and Siri for the two discount ratio of 5% and 18% are described in table 6.

Table 6. Payback period and Net present value for Marun and Siri's flare gas

	Payback period(yr)	Net Present value(5%)(US\$)	Net Present value(18%)(US\$)
Marun	6.24	42,349,415.32	-16,379,920.84
Siri	4.23	267,107,391.88	13,364,633.24

4. Conclusion

In this paper, the technical and economic feasibility study of recovering flare gas for producing methanol is studied. Because methanol is liquid fuel and is the primary substance for producing other products, and moreover the collecting of all flare gas from different fields is not possible and economic In Iran, It seems that establishing a small unit with low input gas capacity for converting flare gas to methanol in place is affordable. For this reason, firstly, the conceptual design of methanol unit is performed after sweating and separating the heavy hydrocarbons of flare gas. The input gas parameters are related to Marun and Siri, Iran's oil fields flare gas. After simulating and equipment sizing, the cost of equipment is determined and according to this, capital cost and also total product cost is calculated. Then, the production cost is evaluated.

5. Reference

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Biography

Azadeh Maroufmashat obtained her B.Sc. degree in mechanical Engineering in 2007 and her M.Sc. and PhD in Energy system engineering in 2010, and 2015, respectively, all from Sharif University of Technology, Tehran, Iran. During her PhD, she was as a visiting scholar at University of Waterloo. Presently, she is a postdoctoral fellow in the Department of Chemical Engineering at the University of Waterloo. Her areas of interests are the integration of energy systems, Energy Hub Modeling, Optimization, Power to Gas, as well as Hydrogen Economy.

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