ISSN 2229-5518

Modification of a Natural Gas Dehydration Plant for Improved Performance

Akingbemila Olufemi[1] and Emeka Okafor[2]
[1]Department of Petroleum and Gas Engineering, University of Port Harcourt (UNIPORT), Nigeria.

*Corresponding Author: Akingbemila Olufemi; femigbemila@yahoo.com; +234-803-796-4740
Second Author; Emeka Okafor; emeka.okafor@uniport.edu.ng; +234-706-438-0451

Abstract

Upstream natural gas which consists of light hydrocarbons including methane, ethane, and propane; acid gases such as carbon dioxide and hydrogen sulphide; water; and other impurities, must be conditioned and/or purified to produce gas of marketable quality. The present work focuses on the modification of a real natural gas adsorption and regeneration system located in Western Delta, Nigeria which might be forced to flares over 15 MMSCF of gas valued at over 30,000 US Dollars per day or resort to occasional plant shutdown with corresponding loss of over 80 MMSCFD of gas valued at over 197,000 US dollars per day when the regeneration compressor fails. The presented modification of this natural gas dehydration unit addresses the above mentioned losses by modifying the dehydration/regeneration system without regeneration compressor. The flowsheets of the baseline plant and its modified version consist of one adsorption bed and one regeneration bed simulated using proprietary software (Aspen HYSYS, 2014). Results show that the modified version is flow assured, operable and economically viable, with the cost-effectiveness increasing by a factor of four, and with a lifetime cost value of approximately 30,000 US dollars as against the baseline design which has a lifetime cost value of over 120,000 US dollars.

1. Introduction

Natural gas industries have understood the huge impact of non-hydrocarbon gases availabity in natural gas stream especially water as well as the essence of dehydration process for effective and efficient processing, tranportaion and utilization of natural gas (Marian et al 2016; Qayzin et al 2015; Asgari et al 2014). These non-hydrocarbon gases in natural gas are normally removed or, at least, their concentration is highly reduced, to meet a target level based on pipeline or processing contract terms (Ikoku, 1984; Mokhatab and Wiliam, 2012; Mokhatab et al, 1998; Wang and

Economides, 2009). Water content is the most undesirable for the following reasons: (1) Water in hydrocarbon can form hydrate which can plug pipelines and/or restrict movement of rotational parts of gas processing equipment; (2) Water reaction with acid gases in the natural gas to form acids that can corrode pipelines and other process equipment; and (3) Decrease in the heating value of natural gas due to the presence of water. Thus, it is extremely essential to dehydrate the natural gas so that the identified problem may not occur (Leonel et al, 2017; Mohamad, 2009; Donald and Bill, 2008; Gandhidason et al, 1999). The flowsheet model for the dehydration unit has a profound effect on both operability, profitability and efficiency of the processing facility. The dehydration unit considered in this research comprises of two molecular sieve beds; when one is dehydrating, the natural gas, the other is been regenerated based on adsorption dehydration and regeneration sequence. This paper presents a modified adsorption-regeneration flowsheet model that can enhance the operability and profitability of a real plant existing in Western Delta, Nigeria specifically in case the regeneration compressor that is supposed to send the regerated gas back to the high pressure line for a continuous operation fails. This failure may lead to flaring of about 15 mmsfcd of natural gas if operation must continue without the regeneration compressor. Flaring usually have negative impact on the environment, hence, combination of these issues usually require a total plant shutdown, thus leading to loss of man hour, increase in downtime and loss of revenue (135 MMScfd approximating to about $297,000 per day). This revenue steadily increases until a time when the failed compressor is either repaired or replaced. The proposed modification is aimed at designing a new natural gas flow line on the dehydration unit for continuous and smooth operation of the plant without flaring. We first extract parameters of the original (baseline) natural gas dehydration flowsheet and make an analysis of its operability, performance and cost. After that, a new flowsheet with same feedstock and operating conditions is put forward. Process simulation is applied to obtain adequate required data to make the comparison. The comparison will be based on flow assurance analysis the baseline facility and its modified version, performance analysis, and cost analysis.

2. Description of the process facility

Figure 1 illustrates the original flowsheet (or plant flow diagram) of the dehydration unit within the process facility in Westerm Niger-Delta. The adsorption beds use molecular sieves as the main active desiccant. A multi-stage compression system, including a low-pressure (LP), intermediate pressure (IP) and a high-pressure (HP) compressors, are succeeded by an inlet feedstream to the adsorption bed. The inlet gas from the high pressure (HP) compressor enters the molecular sieve bed at a pressure of 1200 psig and a temperature of 120^{o}F with a flow rate of about 135 mmscfd. The dehydrated "bone dry" gas passes through a dust filter prior to entering the cryogenic section of the plant, the heater carrier gas (15MMSCF) for bed regeneration and the sales gas for export pipeline. The water vapor is almost completely removed from the gas stream during the dehydration cycle (adsorption) and stripped off the second bed during the regeneration cycle. The proposed modification is designed to determine operability, profitability and efficiency of the dehydration unit by introducing a retrofitted gas flowline which will return the regeration gas to high pressure line in case of failure of the regeneration compressor (C200A/B) Figure 1 shows the main adsorption-regeneration system with regeneration compressor, figure 2, show the retrofitted adsorption-regenaration system without the regeneration compressor while figure 3 and figure 4 show the ASPEN HYSYS simulation flowsheet.

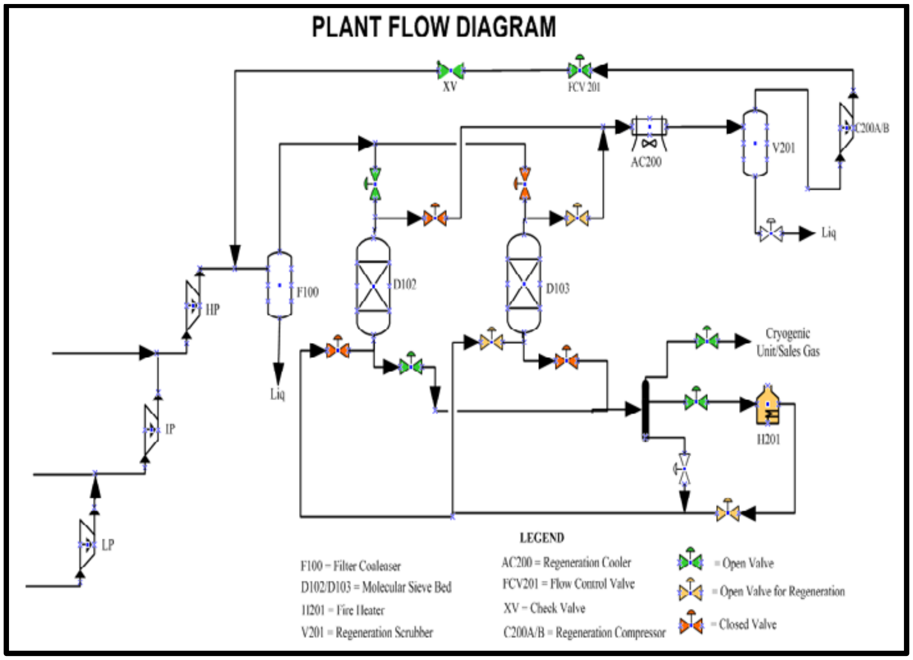

Figure 1: main adsorption-regeneration system with regeneration compressor.

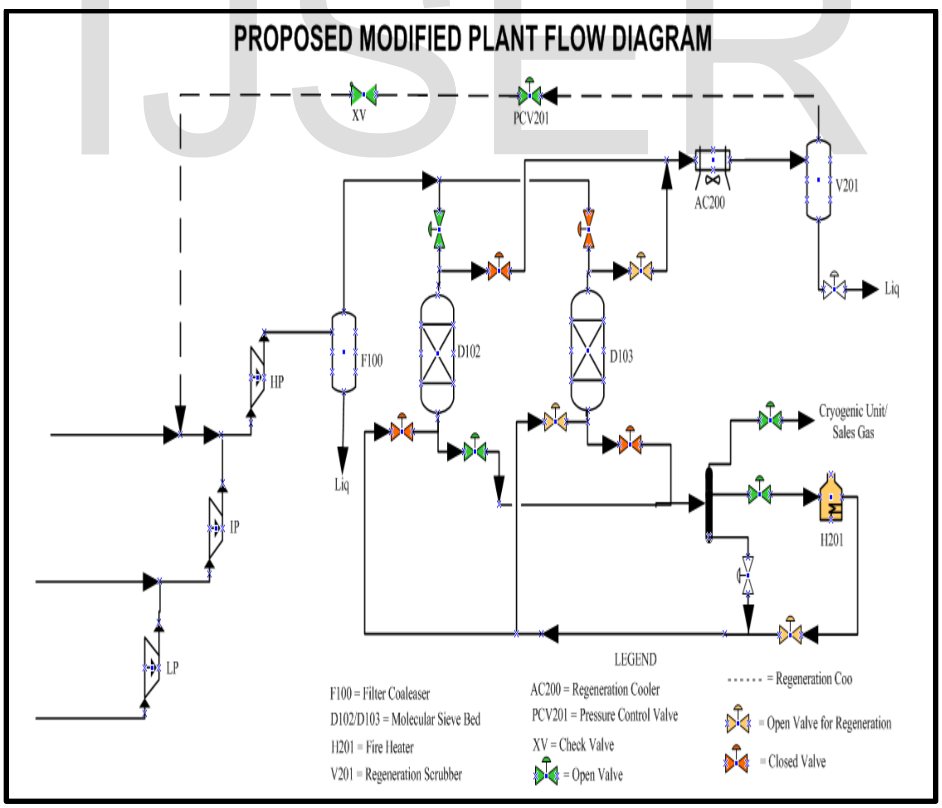

Figure 2: modified adsorption-regeneration system without regeneration compressor.

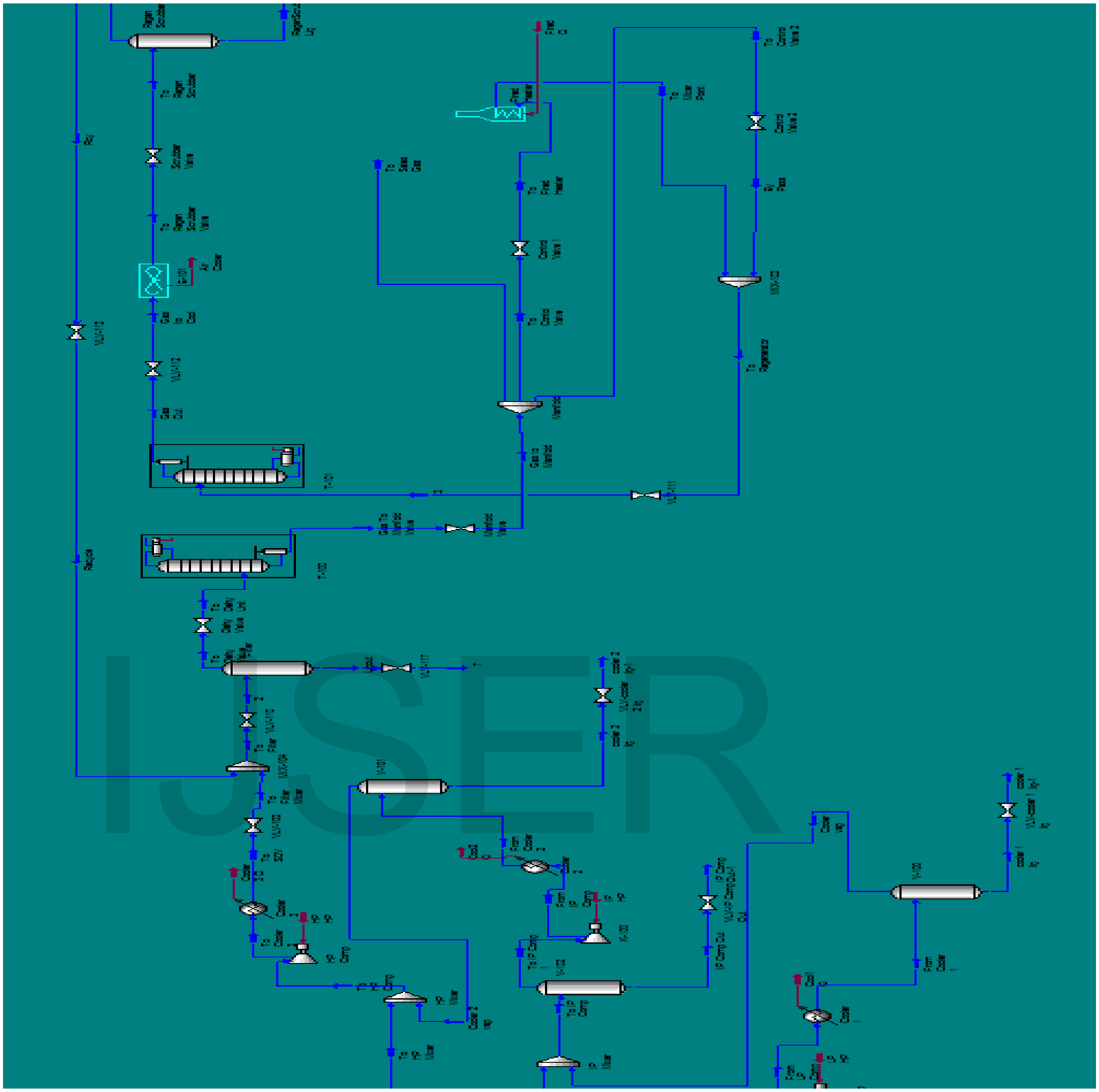

Figure 3: ASPEN HYSYS simulation of main adsorption-regeneration system with regeneration compressor.

ISSN 2229-5518

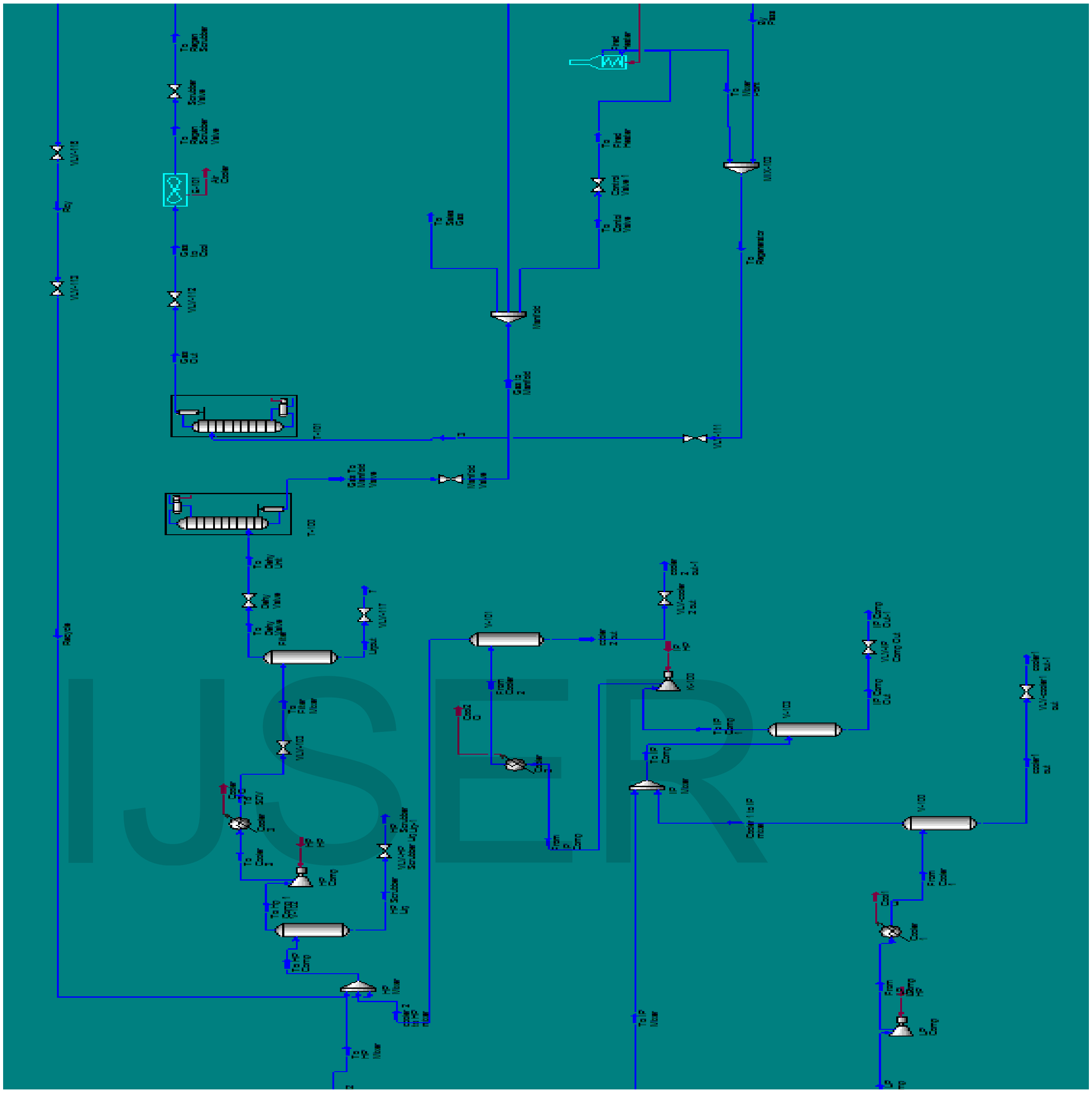

Figure 4 ASPEN HYSYS simulation of: modified adsorption-regeneration system without regeneration compressor.

3. Results from comparison of the original and modified dehydration plants

3.1 Flow assurance

Gas flow assurance analysis may be carried out on the basis of hydrate formation conditions, water saturation conditions and the hydrocarbon dew point conditions. Here, we carry out flow assurance analysis based on the hydrate formation conditions. The feed stream composition of the plant is shown in Table 1. Gas flow upstream of the pressure control valve (PCV201) suggests that both processes are flow assured with no potential for hydrate formation, as Figure 3 indicates. The position of the hydrate formation temperatures is far below the actual gas flow temperature. Although, gas flow temperature steadily dropped when the regeneration compressor was removed but this drop will not in any way result in hydrate formation even as the magnitude of the cooler duty increases. The increase in gas flow temperature in the original plant is obviously attributable to the rise in pressure at the regeneration compressor discharge and which increase ended up reaching the minimum temperature of the gas when regeneration compressor is absent. It is also evident from these results that the modified plant is more flow-assured than the original plant within the considered cooler duty range. Gas flow downstream of the pressure control valve (PCV201) is shown in Figure 4.

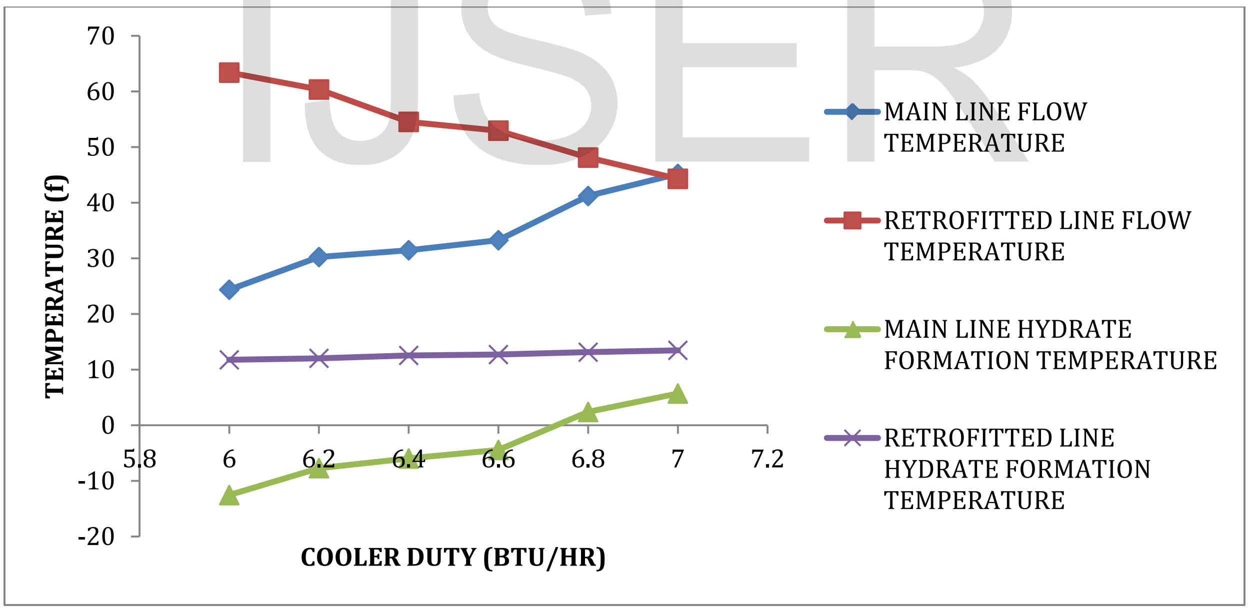

Figure 3: Graphical relationship between flow temperature versus cooler duty upstream of the PCV of the original plant (main line with regeneration compressor) and the modified/retrofitted plant (line without regeneration compressor).

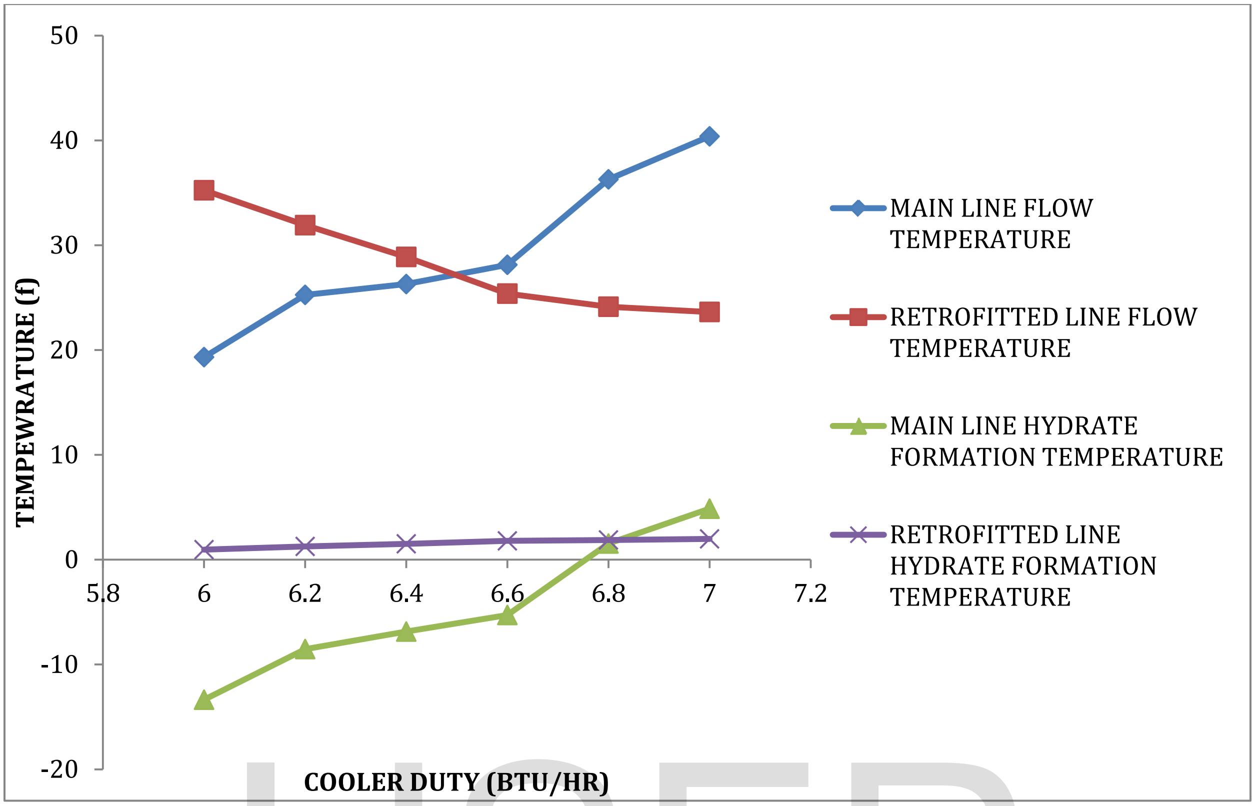

Figure 4: Graphical relationship between flow temperature versus cooler duty downstream of the PCV of the original plant (main line with regeneration compressor) and the modified/retrofitted plant (line without regeneration compressor).

3.2 Performance Analysis

A performance analysis compared the results obtained from the two different processes (i.e. the original plant/main line versus the modified line) on the basis of the total energy consumption. The following simplistic percentage formulae was used for the computation,

$$\text{Performance} = \frac{\text{total energy input in the main line} - \text{total energy input in the modified line}}{\text{total energy input in the main line}} \times \frac{100}{1}$$

Positive values of the above computation imply that there is an increase in the performance of the modified flowsheet while a negative value suggests that the reverse would be the case. However, a zero value suggests that the performance of each of the two process did not change. Table 1 tabulates some results of this comparison while the actual performance is given as,

$$\text{Performance} = \frac{12{,}962.64 - 11{,}019.10}{12962.64} \times \frac{100}{1} = 14.99\%$$

This results implies that by using the modified flowsheet, approximately 15% less energy consumption is achieved, thereby indicating that the modified line should be more operable, profitable and cost-effective.

Table 1; Main line energy input

UNIT OPERATIONS	**MAIN PLANT ENERGY INPUT (kw)**	**MODIFIED PLANT ENERGY INPUT (kw)**
HP Compressor	6975	4969
IP Compressor	2572	2350
LP Compressor	1361	1361
Regeneration compressor	3.64	-
Heater fired heater	2051	2339.10
TOTAL ENERGY INPUT	12,962.64	11, 019. 20

3.3 Cost estimation

Natural gas processing facilities are capital projects and would require large commitment of funds. Its impact on the financial wellbeing of an organization extends over a long period. It is therefore necessary that operation and maintenance cost of the dehydration unit does not exceed its value. According to Iledare (2015), various profitability measures have been developed to aid decision makers choose between several investment alternatives; these measures help rank a projects' profitability based on the profitability measures including: net present value (NPV), payback period (PP), average return on investment (AROI), internal rate of return (IRR), growth rate of return (GRR), profitability index (PI), unit technical cost (UTC), and expected monetary value (EMV). In this work, we employ the use of NPV and Profitability Index (PI), as shown in Table 2. NPV is simply the sum of individual cash flows for each year over the entire field project life. It is the present value of the cash flow, applying 15% discount rate. It was observed that the net present value of the cash flow is high because of revenue generated from gas sales. It can be calculated thus:

$$NPV = \sum_{t=1}^{n} \frac{NCF}{(1+i_d)^t}$$

Where NCF is net cash flow, i_d is discount rate, and t is time.

The NCF for the dehydration with the regeneration gas compressor and the modified proposed process are the same with respect to the amount of gas per year. In order words, plant availability of 96% (350 days) was used to determine the NCF at $2.2 per MScf and average production of 45 MMScf/d.

MMScf = 1000 MScf = 1000 x $2.2 = $2200

NCF = days/yr. x Volume Produced x Cost of Gas

= 350 x 45 x $2200

= $34, 650, 000

Where MScf denotes a thousand cubic feet and MMScf, a million cubic feet.

Table 2: Capital budgeting decision rule

Profitability measures	Accept if @ r	Reject if @ r
Payback period	≤desired	≥desired
NPV	>0	<0
EMV	>0	<0
IRR	>r	<r
PI	>1	<1
PVR	>0	<0
GRR	>r	<r

Since, the revenue of both dehydration with regeneration gas compressor and the modified line are the same, we will no longer base the analysis on the net present value of revenue but on the net future value of expenses both for the capital and operational/maintenance cost. Hence, we chose net future value (NFV) and define it in this content as the sum of all the cost that will be incurred in the assumed life time of the designs, which is given as:

$$NFV= \sum NC\ (1+r)^n$$

Where NC is the net cost for each year, r is the assumed interest rate, and n is the number of years.

The profitability analysis is based on the NFV of the cost of installation of the two processes and the array of the cost of maintenance of the project over ten years. Some of the assumptions of the net future value are:

(1) The interest or discount rate is the same throughout the months of the years and the entire years under investigation and is fixed at 15%;

(2) The avearge value of the project after the years under investigation equals zero; and

(3) The maximum useful life of the project is ten years.

While the net future value formula is stated above, the estimated initial costs of installation as well as the yearly cost of maintenance of the two projects are presented in Table 3, 4 and 5.

Table 3: Installation and maintenance cost

DEHYDRATION UNIT WITH REGENERATION GAS COMPRESSOR (PROJECT A)				
	ITEM DESCRIPTION	QUANTITY	UNIT COST($)	AMOUNT ($)
1	Sundyne Regeneration Compressor Package	2	15, 000	30, 000
2	Check Valve	1	600	600
3	Flow Control Valve	1	800	800
4	6” Pipe	0.5	400	200
5	Flanges	12	100	1200
6	Gaskets	6	25	150
7	Studs	72	4	288
8	Elbow	2	40	80
9	Cost of Maintenance per year - Sundyne Oil/drum - Oil Filter - Labor (2 Technicians)	 1 8 4	 2000 40 280	 2000 + 320 1120
				Subtotal 3440
10	Cost of Installation (4)	4	560	2240
		Total	**38,998**	
DEHYDRATION UNIT WITH MODIFIED LINE (PROJECT B)				
1	Isolation Ball Valve	2	125	250
2	Check Valve	1	600	600

3	Pressure Control Valve	1	800	800
4	6” Pipe	10	400	4000
5	Flanges	22	100	2200
6	Gaskets	11	25	275
7	Studs	132	4	528
8	Elbow	6	40	240
9	Cost of Maintenance per year - Grease/qtr. - Labor (2 Technicians)	 1 2	 1 280	 1 560
				561
10	Cost of Installation (5)	7	700	4900
			Total	**14, 354**

Note, cost of three (3) yearly pipe integrity check = $250

Table 4; Net future value of the main line

Year	Cost ($) (C)	Discount factor $(1+r)^n$	Discount value $C(1+r)^n$ ($)
0	38,998	1.000	38,998
1	3440	1.150	3956
2	3440	1.323	4550
3	3440	1.521	5231
4	3440	1.749	6061
5	3440	2.011	6918
6	3440	2.313	7957
7	3440	2.660	9150
8	3440	3.059	10523
9	3440	3.518	12101
10	3440	4.046	13916

$$\text{NFV} = \sum Discount\ value = \$\ 119{,}361$$

Table 5: Net futre value of the modified line

Year	Cost ($) (C)	Discount factor $(1+r)^n$	Discount value $C(1+r)^n$ ($)
0	14,354	1.000	14,354
1	561	1.150	645.2
2	561	1.323	742.1
3	811	1.521	1233.4
4	561	1.175	981.2

5	561	2.011	1106.9
6	811	2.313	1875.9
7	561	2.660	1492.3
8	561	3.059	1716.1
9	811	3.518	2852.9
10	561	4.046	2269.6

$$\text{NFV} = \sum Discount\ value = \$29{,}269.6$$

From the computed values, the net present value of cost for the main line is $ 119,361 which is four times the net present value of cost for the modified line (i.e. $29,269.6). This suggests that the modified line would be four times more profitable than the main line in terms of cost estimation. Figure 5 is an alternative illustration of the comparative results.

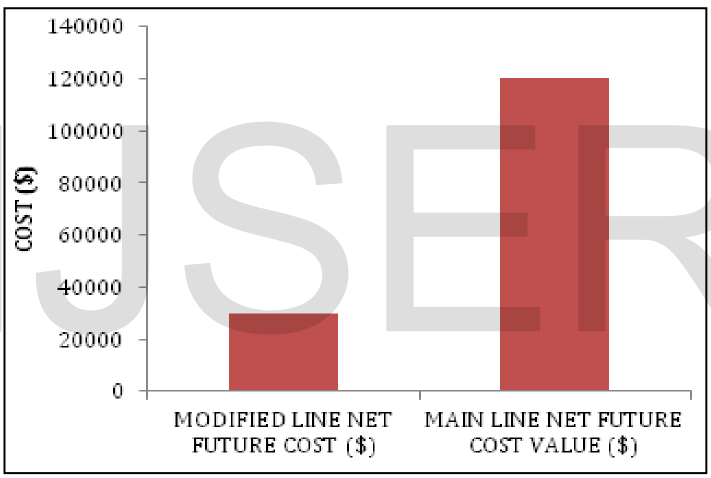

Figure 5: Bar chart of net future value of cost for the main line and the modified line.

4. Conclusion

This paper presents an optimized flowsheet model for an existing natural gas dehydration plant. Two processes are fully simulated under the same feedstock and product specifications. For comparison, we extract the process data and perform flow assurance analysis, performance evaluation, and cost estimation (economic evaluation). Three conclusions can be drawn from this study. Firstly, the modification of the flowsheet is feasible and flow assured by removing the regeneration compressor in case of failure, and the modified plant performance increased following this modification. Secondly, the enhancing modification can lead to increased profitability of the plant with increased revenue and reduced downtime. Thirdly, the capital cost of the regeneration compressor is relatively high, thus, the new process that excludes this equipment can increase revenue, while completely omitting the compressor maintenance option.

At the upstream of the pressure control valve, and within the designed and simulated cooler duty range of 6.0×10^6 btu/hr to 7.0×10^6btu/hr, a combined analysis of the two lines indicates that the modified line is more flow assured than the main line/regeneration compressor. At the downstream of the pressure control valve, and within the cooler duty range of 6.0×10^6 btu/hr to 7.0×10^6btu/hr, a combined analysis of the two lines indicate that the modified line is more flow assured within the cooler duty range of 6.0×10^6btu/hr to 6.42×10^6btu/hr, while the main line is more flow assured within the cooler duty range 6.42×10^6btu/hr to 7.0×10^6btu/hr,

The performance analysis on both lines indicates that the modified line is 14.99% more energy effective than the main line on the basis of energy consumption. The profitability analysis of the two lines using net future value (NFV) of cost as the parameter indicates that the modified line is four times more cost effective than the main line having a net future cost values of $29,269.6 and $119,261 respectively. With the modified line, there is certainty in an uninterrupted operation; high percentage recovery, high plant availability, high production up-time [>96%] to achieve zero flare target which is the basic requirement for Clean Development Mechanism (CDM) Audit.

To avoid a total plant shutdown in the face of poor logistics, unavailability of spare parts and high financial constraints which may lead to loss of man hour, increase in down time and high loss of revenue (135 MMScfd approximating to about $297,000 per day), the modified system should be adopted and incorporated in future plant designs as an option or an alternative use. This will ensure optimum dehydration performance with added afficiency of the plant.

References

Ahmad S (2009). Natural gas dehydration using triethyleneglycol (TEG), Faculty of Chemical and Natural Resources Engineering, University Malaysia Pahang.

Asgari M., Anisi M., Mohammadi H., Sadighi S., (2014) "Designing a Commercial Scale Pressure-Swing Adsorber for hydrogen purification", Journal of Petroleum and Coal, no56 vol (6):pp552 561.

AspenTech. (2009). Aspen HYSYS User's Guide, Aspen Technology Inc.

Aspen HYSYS (2014). Training manual, version 8.4.

Donald W and Bill, W. (2008). The adsorption process, Technical Article Progam (TAP), Donaldson Company Inc.

Farman S (2004). A Study of the dehydration process of natural gas in Iraq North Gas Company Farman Saeed Abd. Zangana, and the Treatment Method of Molecular Sieve Problems.

Gandhidason P and AL Farayedhi A (1999). PC program estimated TEG circulation rate Number of tray, O*il and Gas Journal,* **5**.

Ikoku, C. U. (1984). Natural gas production engineering, John Wiley & Sons. New York.

Leonel G, Yuly A. Poveda, M. Ki and Gerardo R (2017) "Synthesis and Granulation of a 5A Zeolite-Based Molecular Sieve and Adsorption Equilibrium of the Oxidative Coupling of Methane Gases" Journal of Chemical Engineering Research. no62 vol4, pp 1550–1557

Mirian, S., Anisi, H., Xiang, Y., Sadighi S. (2016) "Reflux in a gas dehydration plant", Journal Petroleum Quarterly Technology (PTQ), Q4, pp75-79.

Mokhatab, S. and William, A.P. (2012). Natural gas dehydration, *Handbook of Natural Gas* transmission and Processing, 7.

Qazvini O.T., Fatemi S. (2015), "Modeling and simulation pressure–temperature swing

ISSN 2229-5518

adsorption process to remove mercaptan from humid natural gas; a commercial case study", Journal of Separation and Purification Technology, vol139: pp88 103

Saeid Mokhatab, William A. Poe, and James G. Speight (1998). Handbook of natural gas transmission and processing.

Xuili Wang and Micheal Economides (2009). Advanced Natural Gas Engineering. Gulf publication Company, Houston, Texas,