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Design of a Gas Turbine for the Conversion of Flare Gases to Energy Using Aspen HYSYS: A Case Study of an Oil Field in Niger Delta

Appolos Gombando Osaro*, Awajiogak A. Ujile, Ademiluyi, Falilat Taiwo
Department of Chemical / Petrochemical Engineering,
Rivers State University, Port Harcourt, Rivers State, Nigeria

ABSTRACT

Gas flaring is among the main issues being discussed in the oil and gas industry for decades now. The present study is motivated by concerns over the environmental impact associated with gas flaring activities in the industries and the economic waste. The case study selected was from an oil mining lease in Nigeria. A total volume of gas flared daily for a period of June, July and August, 2022 along with the analyzed composition of the flare gas was collected. The volume of gas flared daily was estimated as 13,000 Sm^3 per day which is equivalent to 542 m^3/h flowrate. The combined cycle energy plant (gas turbine-steam turbine systems) simulation carried out in Aspen HYSYS v.10 using Peng-Robinson fluid package, a 98.61% removal of CO_2, H_2S and other heavier hydrocarbons in the flare gas was achieved in the flare gas absorber and separator units. The net energy output from the combined turbine plant was found to be 346.5MW of electricity daily; this is sufficient enough to power Port Harcourt city. Estimation of the total capital and operating costs was performed using Aspen Process Economic Analyzer (APEA), total capital cost of 67,907,300 USD, total operating cost of 19,345,800 USD/Year, total utilities cost of 14,247,500 USD/Year, equipment cost of 45,097,500 USD, and total installation cost of 48,724,000 USD. This shows that the model used in this work can solve the problem of gas flaring in an oil mining lease in Niger Delta.

Keywords: Combined cycle energy, Combined turbine plant, Energy generation, Energy relations, Flare gas treatment, Gas conversion, Simulation software

INTRODUCTION

Gas flaring has been a problem plaguing the oil and gas industry in recent years (Hassan & Kouhy, 2013). Gas flaring is the process of burning excess natural gas in the atmosphere during oil and gas production and processing operations. According to World Bank estimates, the amount of gas flaring in the oil and gas sector globally in 2020 was 142 billion cubic meters (Mansoor & Tahir, 2021), which is comparable to the whole annual industrial usage of France and Germany. For the ninth year in a row, Russia, Iraq, Iran, the United States, Algeria, Venezuela, and Nigeria have been the top seven gas-flaring countries (Abu *et al.*, 2023). Approximately 65% of worldwide gas flaring is accounted for by these seven nations, while producing 40% of the world's oil annually (World-Bank, 2021). Although these concerning numbers also come from petrochemical and hydrocarbon processing facilities, the upstream sector—that is, oil and gas production platforms—contributes the most to the amount of gas burnt.

Nigeria is the greatest contributor to flaring on the continent, having the highest known gas reserves (Akinola, 2018). Nigeria flared up to 10.027 billion Standard Cubic Feet of gas in December 2022, up from 9.3 billion the previous month (Addeh, 2023). The Nigerian Federal Government lost around N843 billion due to gas flaring between January 2022 and

* Corresponding Author

August 2023 (Akintayo, 2023). As a result, environmental and economic considerations have urged that flare gas recovery (FGR) systems be used in this region.

Ofon Field is an oil and natural gas field located in the Oil Mining Lease (OML) 102, about 65km offshore in the south-eastern coast of Nigeria. The reserves lie at a water depth of 40m (131ft). The proved and probable reserves at Ofon are about 350 million barrels of oil equivalent. Phase one of Ofon Field started production in December 1997 (Verdict, 2016). Phase two of the offshore Ofon Field development began in February 2012 and production commenced in January 2015. Phase two taps the undeveloped reserves at the Ofon Field. The development mostly focuses on producing natural gas. The recovered gas from the field is being compressed and transferred to the shore. The development works towards reducing greenhouse gas emissions and flaring of associated gas (Verdict, 2016). In line with TotalEnergies environmental stewardship commitments, Ofon Phase 2 is a major step forward in the Group's plan to reduce its flaring of associated gas and its greenhouse gas emissions (Jacques, 2012).

Aspen HYSYS is a widely used process simulation software in the oil and gas industry (Edwin *et al.*, 2017). Aspen HYSYS is a steady-state process simulator for process design, modelling and operational analysis for process engineers in the chemical, petroleum, natural gas, solids processing, and polymer industries. It includes a chemical component library, energy property prediction methods, and unit operations such as distillation columns, heat exchangers, compressors, turbines, storage tanks, reactors, absorbers, separators, etc., as found in the chemical processing industries. It can perform steady-state mass and energy balance calculations for modelling continuous processes. An important characteristic of Aspen HYSYS is the ability to interface with other software and tools. The integration with Aspen Process Economic Analyzer (APEA), Microsoft Excel, and other external tools enhances its functionality and allows for a more comprehensive analysis of the entire process.

Research was conducted on Simulation and Economic Evaluation of Heat and Power Generation from Flare Gases in a Combined Cycle Power Plant (Jafari *et al.*, 2020), their study showed that PRO/II Simulation software was used to simulate a gas turbine and a steam turbine power plant, a flare gas consumption of 1075m^3/h which is approximately 25800m^3 daily was used in the simulation to generate a net energy output of 113MW daily. An analysis was performed on Technical and Economic Analysis use of Flare Gas into Alternative Energy as a Breakthrough in Achieving Zero Routine Flaring (Petri *et al.*, 2018), in their study, Aspen HYSYS simulation software was used to simulate the power plant, a flare gas consumption of 0.584MMSCFD which is approximately 16536m^3 daily was used in the simulation to generate a net energy output of 1.3MW daily. According to a study on Simulating Combined Cycle Gas Turbine Power Plants in Aspen HYSYS (Liu & Karimi, 2018), their study showed that Aspen HYSYS simulation software was used to simulate a gas turbine and a steam turbine power plant, a flare gas consumption of 14.74kg/s which is approximately 3590.4m^3 daily was used in the simulation to generate a net energy output of 393MW daily. A study was done on Economics of Gas to Wire Technology Applied in Flare Gas Management (Ojijiagwo *et al.*, 2016). The data obtained showed that the gas producing company flares about 8.33% of its total production, their study demonstrated that flare gas consumption of 0.93MCM which is approximately 930,000m^3 generated 150MW of electricity daily. Based on their findings, it was inferred that electricity generation through GTW is a viable technology to achieve flare gas reduction, particularly in Nigeria.

The focus of this paper is to contribute to the enhancement of knowledge through the use of energy models and simulations to optimize the design and operation of systems aimed at reducing or recovering flare gases from a flaring gas source in an oil mining lease, OML 102, Ofon field in Niger Delta. This is achieved by adopting the following objectives to:

i. Evaluate and explore the use of flare gas for energy generation.

ii. Refine the flare gas, separate the toxic and dangerous gases of H_2S, CO_2 and other heavier hydrocarbons, and bring the concentration of these gases to a standard and acceptable level that can be used for energy generation.
iii. Use process simulation software called Aspen HYSYS v.10 to design and model an energy generation plant using flare gases as feedstock.
iv. Estimate the size and cost of the plant, and the amount of energy that could be generated from the flare gas of an oil mining lease in Niger Delta with specific design capacity.

MATERIALS AND METHODS

Materials

The materials used in carrying out the research are as follows: Computer, Aspen HYSYS v.10, Calculator (ST-991ES PLUS), Laboratory analyzed result of flare gas sample collected from an oil mining lease in Niger Delta.

Methods

The study was done on a flare gas sample taken from an oil mining lease in Niger Delta. The volume of gas flared daily for a period of three months for June, July and August, 2022 along with the analyzed composition of the flare gas was collected. Given the nature of the flare gas commonly collected, two systems for heat and energy generation were used in the simulation as shown in Figure 1; a Gas Turbine (GT) and Steam Turbine (ST) systems were taken into consideration for the simulation. The goal was to refine the flare gas, separate the toxic and dangerous gases of Hydrogen Sulphide (H_2S), Carbon Dioxide (CO_2) and other heavier hydrocarbons, and bring the concentration of these gases to a standard and acceptable level. The treated flare gas for the generation of energy entered the gas station's energy plant. Moreover, the operating conditions in Table 1 are for the conversion of flare gas to energy, the composition of feeds and the volume of feeds are tabulated in Table 2 and Table 3 respectively.

In this study, Aspen HYSYS was used to simulate all chemical processes, modelling, performance enhancement, and process optimization. As the most enhanced model in Aspen HYSYS, the Peng Robinson fluid package is employed for simulation in the current study.

Table 1: Operating Conditions for the Conversion of Flare Gas to Energy

Parameter	Unit	Value
Flare Gas		
Temperature	°C	27.00
Pressure	kPa	101.32
Flowrate	m^3/h	542.00
Atmospheric Air		
Temperature	°C	25.00
Pressure	kPa	101.32
Flowrate	m^3/h	5440.00
Boiler Feed Water (BFW)		
Temperature	°C	35.00
Pressure	kPa	101.32
Flowrate	m^3/h	541.51
Compressor		
Pressure	kPa	1013.2
Adiabatic Efficiency	%	90.3
Pressure Ratio		10.0
Gas Turbine		
Temperature	°C	1200
Isentropic Efficiency	%	84.6
Steam Turbine		
Temperature	°C	550
Isentropic Efficiency	%	83.3
Pump		
Temperature	°C	35.02
Pressure	kPa	506.6
Adiabatic Efficiency	%	87

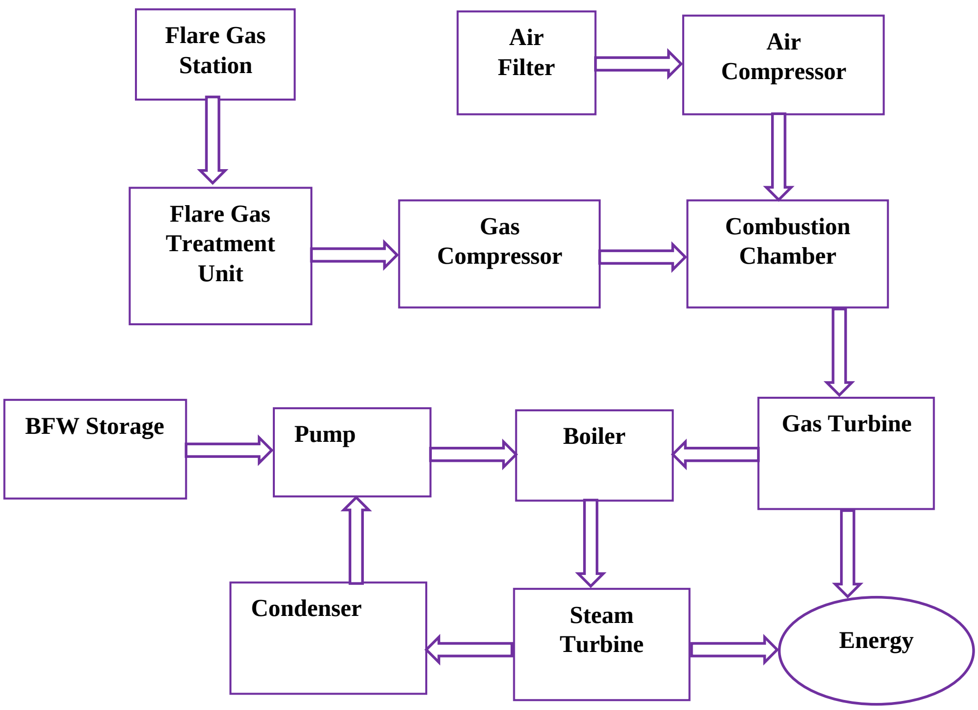

Figure 1: Block Flow Diagram for Conversion of Flared Gases to Energy

Table 2: Component and Composition of Feeds

S/N.	Component Name	Formula	Composition (%)
Flare Gas Composition			
1	Methane	CH_4	80.56
2	Ethane	C_2H_6	6.99
3	Propane	C_3H_8	6.26
4	Iso-Butane	C_4H_{10}	1.11
5	N-Butane	C_4H_{10}	1.97
6	Iso-Pentane	C_5H_{12}	0.50
7	N-Pentane	C_5H_{12}	0.36
8	N-Hexane	C_6H_{14}	0.24
9	N-Heptane	C_7H_{16}	0.17
10	N-Octane	C_8H_{18}	0.15
11	Carbon Dioxide	CO_2	0.71
12	Hydrogen Sulphide	H_2S	0.00
13	Water	H_2O	0.00
14	Nitrogen	N_2	0.98
Air Composition			
1	Oxygen	O_2	21.00
2	Nitrogen	N_2	78.00
3	Aerosols*	$Al_2O_3(SiO_2)_2(H_2O)_2$	1.00
MDEA Composition			
1	Methyldiethanolamine (MDEA)	$C_5H_{13}NO_2$	40.00
2	Water	H_2O	60.00
Boiler Feed Water (BFW) Composition			
1	Water	H_2O	100.00

Table 3: Volume of Feeds

Parameter	Unit	Value
Flare Gas	m^3/h	542.00
Atmospheric Air	m^3/h	5440.00
Boiler Feed Water	m^3/h	541.50

Material and Energy Relations

The energy equations applied to each of the process units are described below.

(i) The Power, P (kW) Consumed by the Motor of a Pump

The ideal power, P required to drive a pump depends on the volumetric flow rate of the fluid, Q_v (m^3/hr), the fluid density, ρ (kg / m^3) and the differential height or head created by the pump, H_p (m) and is given in equation 1 as (Ujile, 2014)

$$P = \frac{Qv\,\Delta P}{1000\eta} = \frac{Qv\,\rho g Hp}{1000\eta} \tag{1}$$

(ii) Mass Transfer between Fluids

The driving force of a mass transfer process, m (kg/hr), mass transfer coefficient, k_y, k_x (m/hr), interfacial area, A (m^2) and the log mean concentration difference $(\Delta y, \Delta x)lm$ (kg/m^3) with respect to the gaseous and liquid phases is expressed in equation 2 and 3 as (Ujile, 2014):

$$m = k_y A\,(\Delta y)lm \tag{2}$$

Or

$$m = k_x A\,(\Delta x)lm \tag{3}$$

(iii) Specific Heat Capacity (kJ/kgmol-^{o}C)

The amount of sensible heat required to raise the temperature of a unit mass of material by one degree. It is expressed in equation 7 as:

$$c = \frac{\Delta Q}{m\Delta T} \tag{4}$$

(iv) Energy Balances (kJ)

The steady-state energy balance determines the heat and work interaction between a system and its surroundings. The equation is given as

$$Q - W = \Delta H + \Delta KE + \Delta PE \tag{5}$$

Where Q (kJ), heat transfer, W (kJ), work transfer, ΔH (kJ), enthalpy change, ΔKE (kJ), kinetic energy change and ΔKE (kJ), potential energy change.

(v) General Material Balance Equation

$$\begin{pmatrix} Rate\ of\ accumulation \\ of\ component\ A \\ within\ the\ reactor \end{pmatrix} = \begin{pmatrix} Rate\ of\ input \\ of\ component \\ A \end{pmatrix} - \begin{pmatrix} Rate\ of\ output \\ of\ component \\ A \end{pmatrix} \pm \begin{pmatrix} Rate\ of\ generation\ or \\ deplection\ of\ species\ A \\ by\ chemical\ reaction \end{pmatrix} \tag{6}$$

(vi) Material Balance of an Absorber

Expressing the concentration of the component being absorbed in the gas and liquid as a mass or mole ratio (Ujile, 2014),

$$m = G(yb - yt) = L(xb - xt) \tag{7}$$

(vii) Material Balance of a Separator

Flow rate in = Flow rate out at steady-state, accumulate rate = 0

$$GmY_1 + LmX_1 = GmY_2 + LmX_2 \tag{8}$$

But $X_1 = 0$,

$GmY_1 = GmY_2 + Lm\ X_2$

$0 + GmY_1 = GmY_2 + Lm\ X_2$

$Gm\ (Y_1 - Y_2) = Lm\ X_2$

$$X_2 = \frac{G_m}{L_m}(Y_1 - Y_2) \tag{9}$$

(viii) Mass Flowrate (kg/hr)

Mass flowrate is the ratio of the change in mass of a flowing fluid (dm) with the change in time (dt).

$$\dot{m} = \frac{dm}{dt} \tag{10}$$

(ix) Molar Flowrate (kmol/hr)

Molar flowrate is the number of moles of a fluid (n) flowing through an area per unit time (dt).

$$N = \frac{n}{dt} \tag{11}$$

(x) Volumetric Flowrate (m^3/hr)

Volumetric flowrate is the ratio of the change in the volume of a fluid (dV) with change in time (dt).

$$Q = \frac{dV}{dt} \tag{12}$$

(xi) Heat Flowrate (kJ/hr)

Heat flowrate is the amount of heat that is transferred per unit time in a fluid.

$$Q = \frac{mCp(Ts - Tf)}{t} \tag{13}$$

Process Description of the Flare Gas Conversion System

The flare gas conversion process is simulated by Aspen HYSYS software, as depicted in Figure 2. The Peng-Robinson equation is used as a fluid package in the simulation because of its accuracy in predicting the energy properties of hydrocarbon systems, which are prevalent in the oil and gas industry.

The plant consists of a series of storage systems, gas and air treatment systems, compressors, pump, combustion system, boiler system and turbine systems. Flare gas is transported from the Flare Gas Station at 27ºC and 101.3kPa at a flow rate of 542 m^3/hr as shown in Table 3 to the Flare Gas Storage Tank where it is cooled to -5ºC to facilitate flash separation of the gas in the separator. The cooled flare gas upon entering into the flare gas separator is split into two streams, the bottom stream which is the condensate (heavier hydrocarbons) which is then delivered to the condensate storage tank, while the top stream contains primarily gas and exits the flare gas separator as separated gas. The separated gas enters the flare gas absorber through the down section while Methyldiethanolamine (MDEA) at 27ºC and 101.3kPa at a flow rate of 1375 m^3/hr enters through the up section of the absorber where MDEA scrubs off CO_2 and H_2S from the separated gas via counter-current flow and contact process. Rich MDEA is discharged from the bottom of the absorber while treated gas is discharged from the top at 27.32ºC and 101.3kPa at a flow rate of 525.8 m^3/hr. The treated gas is then compressed to 1013kPa and 224.7ºC in the gas compressor.

The air filter receives atmospheric air at 25ºC and 101.3kPa at a flow rate of 5440 m^3/hr and filters out all solid particles, moisture and particulate matter (aerosols) from the air. The filtered air at 25ºC and 99.32kPa at a flow rate of 5281 m^3/hr is compressed to 1013kPa and 335.1ºC in the air compressor. The compressed gas and compressed air enter the combustion chamber where it mixes and burns at a very high temperature of 1200ºC and pressure of 1013kPa by conversion reaction to create the mechanical energy required to do work. The hot exhaust from the combustion chamber at a flow rate of 5651 m^3/hr enters the gas turbine as flue gas by isentropic expansion process to drive the generator shaft and blades which produces energy and rejects the residual heat as exhaust heat at 800ºC and 194.2kPa.

Boiler Feed Water (BFW) enters the storage tank at 35ºC and 101.3kPa at a flow rate of 541.5 m^3/hr where it is pumped to the boiler at 35.02ºC and 506.6kPa. The pumped BFW and exhaust heat from the turbine enters the boiler through the tube and shell sides respectively where heat is exchanged by thermal contact between the two working fluids. Waste heat exits through the outlet of the shell while high pressure steam exits through the outlet of the tube at 550ºC and 506.6kPa. The high-pressure steam is then transported to the steam turbine where it expands through the generator shaft and blades by isentropic expansion process to produces energy and rejects the residual steam as exhaust steam at 250ºC and 101.3kPa at a flow rate of 541.5 m^3/hr. The exhaust steam is further sent to the condenser where it is condensed into liquid at 35ºC and 101.3kPa and further recycled to the BFW Storage Tank. The resultant work done by the gas turbine and the steam turbine produces energy that will be transmitted to the national grid. The specifications of flare gas were tabulated. The main components and composition of the feeds considered were mentioned in Table 2.

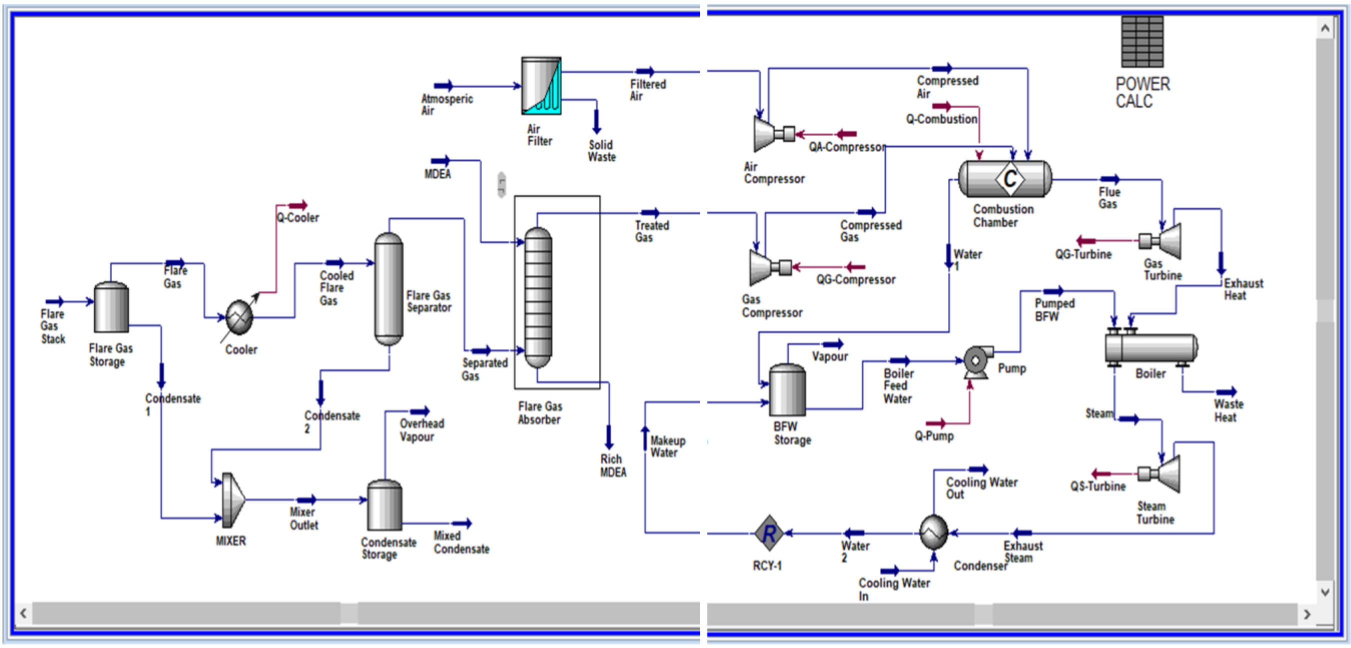

Figure 2: Process Flow Diagram for Conversion of Flare Gases to Energy Simulated in Aspen HYSYS

RESULTS AND DISCUSSION

Composition of Flare Gas at Treatment Unit

Table 4 shows the summary of the composition of flare gas at treatment unit extracted from the Aspen HYSYS Simulation. The flare gas treatment (FGT) unit consist of three streams which are: flare stack (Inflow), condensate 1 (Outflow 1), flare gas (Outflow 2). The composition of condensate recovered from the flare gas are 48.95% n-Octane, 17.73% n-Heptane, 7.94% n-Hexane, 5.8% n-Butane, 5.07% Propane, and other components which have minor composition in the stream. This indicates that some heavier hydrocarbons in the flare gas settle at the bottom of the FGT unit and it is recovered as condensate.

Table 4: Composition at Flare Gas Storage Unit

Components	Flare stack	Flare gas	Condensate 1
Air	0.00	0.00	0.00
Oxygen	0.00	0.00	0.00
Methane	0.8056	0.8056	0.0316
Ethane	0.0699	0.0699	0.0155
Propane	0.0626	0.0626	0.0507
i-Butane	0.0111	0.0111	0.0232
n-Butane	0.0197	0.0197	0.0580
i-Pentane	0.0050	0.0050	0.0377
n-Pentane	0.0036	0.0036	0.0363
n-Hexane	0.0024	0.0024	0.0794
n-Heptane	0.0017	0.0017	0.1773
CO_2	0.0071	0.0071	0.0007
Nitrogen	0.0098	0.0098	0.0001
H_2O	0.00	0.00	0.00
H_2S	0.00	0.00	0.00
MDEAmine	0.00	0.00	0.00
CO	0.00	0.00	0.00
n-Octane	0.0015	0.0015	0.4895

Table 5 shows the summary of the Composition of Flare Gas at Separator Unit extracted from the Aspen HYSYS Simulation. The flare gas separator (FGS) unit consist of three streams which are: Cooled Flare Gas (Inflow), Separated Gas (Outflow 1), Condensate 2 (Outflow 2). The composition of condensate recovered from the flare gas at the Flare Gas Separator unit are 63.41% n-Octane, 18.22% n-Heptane, 6.5% n-Hexane, and other components which have minor composition in the stream. This indicates that the flare gas flashes upon entering into the FGS and the gas phase is separated from the liquid phase (heavier hydrocarbons) which settle at the bottom of the FGS unit and are recovered as condensate.

Table 5: Composition at Flare Gas Separator Unit

Components	Cooled flare gas	Separated gas	Condensate 2
Air	0.00	0.00	0.00
Oxygen	0.00	0.00	0.00
Methane	0.8056	0.8056	0.0069
Ethane	0.0699	0.0699	0.0048
Propane	0.0626	0.0626	0.0201
i-Butane	0.0111	0.0111	0.0109
n-Butane	0.0197	0.0197	0.0295
i-Pentane	0.0050	0.0050	0.0226
n-Pentane	0.0036	0.0036	0.0235
n-Hexane	0.0024	0.0024	0.0650
n-Heptane	0.0017	0.0017	0.1822
CO_2	0.0071	0.0071	0.0002
Nitrogen	0.0098	0.0098	0.00002
H_2O	0.00	0.00	0.00
H_2S	0.00	0.00	0.00
MDEAmine	0.00	0.00	0.00
CO	0.00	0.00	0.00
n-Octane	0.0015	0.0015	0.6341

Table 6 shows the summary of the Composition of Flare Gas at absorber Unit extracted from the Aspen HYSYS Simulation. The flare gas absorber (FGA) unit consist of four streams which are: Separated Gas (Inflow 1), MDEA (Inflow 2), Treated Gas (Outflow 1), Rich MDEA (Outflow 2). The composition of Treated Gas at the Flare Gas Absorber unit which are 81.76% Methane, 7.0% Ethane, 6.07% Propane, 1.04% i-Butane, 1.73% n-Butane, 1.0% Nitrogen and other components which have negligible composition in the stream. This indicates a 98.61% treatment of flare gas was achieved in the Flare Gas Absorber unit.

Table 6: Composition at Flare Gas Absorber Unit

Components	Separated gas	MDEA	Treated gas	Rich MDEA
Air	0.00	0.00	0.00	0.00
Oxygen	0.00	0.00	0.00	0.00
Methane	0.8056	0.00	0.8176	0.0012
Ethane	0.0699	0.00	0.0700	0.0008
Propane	0.0626	0.00	0.0607	0.0021
i-Butane	0.0111	0.00	0.0104	0.0006
n-Butane	0.0197	0.00	0.0173	0.0020
i-Pentane	0.0050	0.00	0.0039	0.0008
n-Pentane	0.0036	0.00	0.0024	0.0009
n-Hexane	0.0024	0.00	0.0006	0.0014
n-Heptane	0.0017	0.00	0.00	0.0013

CO_2	0.0071	0.00	0.0071	0.0001
Nitrogen	0.0098	0.00	0.0100	0.00
H_2O	0.00	0.00	0.00	0.00
H_2S	0.00	0.00	0.00	0.00
MDEAmine	0.00	1.0000	0.00	0.9876
CO	0.00	0.00	0.00	0.00
n-Octane	0.0015	0.00	0.00	0.0011

Equipment Sizing Results

Table 7 shows the summary of the plant equipment sizing results extracted from the Aspen HYSYS Simulation for flare gas storage, flare gas separator, flare gas absorber, BFW storage, and combustion chamber units. The diameter, height and volume of the equipment are specified.

Table 7: Equipment Sizing Results

Equipment	Diameter (m)	Height (m)	Volume (m^3)
Flare Gas Storage	6.42	18.53	600
Flare Gas Separator	6.42	17.30	560
Flare Gas Absorber	6.42	17.30	560
BFW Storage	6.42	18.53	600
Combustion Chamber	16.91	25.37	5700

Plant Energy Results

Table 8 shows the summary of the plant energy results extracted from the Aspen HYSYS Simulation for air and gas compressor, gas and steam turbine, cooler and pump units. The total amount of energy consumed by the plant is 4.345×10^5 kW and the total amount of energy produced in the plant is 7.811×10^5 kW. The net energy output [kW] from the combined turbine plant was found to be 3.465×10^5 kW which is approximately 346.5 MW of energy generated daily.

Table 8: Plant Energy Results

Parameter	Unit	Energy Consumed	Energy Produced
Cooler	kW	3375	0.00
Air Compressor	kW	4.109×10^5	0.00
Gas Compressor	kW	2.019×10^4	0.00
Pump	kW	69.95	0.00
Gas Turbine	kW	0.00	6.883×10^5
Steam Turbine	kW	0.00	9.282×10^4
Total Energy	**kW**	**4.345×10^5**	**7.811×10^5**

Costing of Plant Results

Table 9 shows the plant cost summary results obtained from Aspen Process Economic Analyzer (APEA) (Version 10, 2016 pricing basis) incorporated in Aspen HYSYS. Total capital cost is the total cost of project in the final design and it includes construction, planning, engineering, relocation, land disposal and mitigation cost which amounts to $67,907,300. Total operating cost is the sum of the cost of goods sold plus operating expenses: operating expenses consist of maintenance, administrative and office expenses and this amounts to $19,345,800 per year. Total utility cost is equal to the sum of all utilities gained from each unit of consumption and this amounts to $14,247,500 per year. Equipment cost is the purchase cost of all equipment used in the plant and this amounts to $45,097,500, finally total installed cost refers to the final cost of designing, fabrication and manufacturing of equipment and this amounts to $48,724,000.

Table 9: Plant Cost Summary

Plant Cost Summary		
Parameter	**Unit**	**Value**
Total Capital Cost	[USD]	67,907,300
Total Operating Cost	[USD/Year]	19,345,800
Total Utilities Cost	[USD/Year]	14,247,500
Desired Rate of Return	[Percent/'Year]	20
Equipment Cost	[USD]	45,097,500
Total Installed Cost	[USD]	48,724,000

CONCLUSION

The research done on the design of a gas turbine for the conversion of flare gases to energy using Aspen HYSYS (a case study of an oil field in Niger Delta) has uncovered the benefits derivable from the waste of flare gas in an oil mining lease in Niger Delta. It evaluated and explored the use of flare gases for energy generation. Additionally, it refined the flare gas, separated the toxic and dangerous gases of H_2S, CO_2 and other heavier hydrocarbons, and brought the concentration of these gases to a standard and acceptable level that was used for energy generation. Finally, it estimated the amount of energy generated from the flare gas in an oil mining lease in Niger Delta with specific design capacity. A total volume of gas flared daily for a period of three months for June, July and August, 2022 along with the composition of the flare gas was collected. The volume of gas flared daily from the station was estimated as 13,000 Sm^3 per day which is equivalent to a flowrate of 542 m^3/h. From the result obtained from the combined cycle energy plant (gas turbine-steam turbine systems) simulation carried out with the most enhanced model in Aspen HYSYS v.10 using Peng-Robinson fluid package, a 98.61% removal of CO_2, H_2S and other heavier hydrocarbons in the flare gas was achieved in the flare gas absorber and separator units, the net energy output [kW] from the combined turbine plant was found to be 3.465×10^5 kW which is approximately 346.5MW of energy generated daily. This is sufficient enough to power Port Harcourt city. Estimation of the total capital and operating costs was performed using Aspen Process Economic Analyzer (APEA) (Version 10, 2016 pricing basis), Total Capital Cost of 67,907,300 USD, Total Operating Cost of 19,345,800 USD/Year, Total Utilities Cost of 14,247,500 USD/Year, Equipment Cost of 45,097,500 USD, and Total Installation Cost of 48,724,000 USD. This shows that the model used in this work can solve the problem of gas flaring in an oil mining lease, OML 102, Ofon field in Niger Delta, the environmental hazards caused by the release of greenhouse gases emitted during gas flaring would be reduced and controlled reasonably. It is recommended that further research should be done to specify in detail the stress for shell and tube material of the boiler and the combustion chamber to allow for the detailed economic evaluation of those equipment, also on the plant layout and to design a prototype of the plant.

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