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TECHNO-ECONOMIC STUDY OF ELECTRICITY GENERATING POTENTIALS OF FLARED GASES IN KOKORI TOWN OF DELTA STATE, NIGERIA

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Abstract: **According to the Department of Petroleum resource (DPR) in its 2018 annual report, 11% of total gas production in Nigeria was flared that year, which translate into about 88.06 BSCF (billions standard cubic feet) of gases that could have been delivered to power plants. This work aims to study the economic benefits of utilizing flared gases for power generation in Nigeria using Kokori Island in Delta State as a case study. Data such as flare volumes and gas turbines fuel consumption were obtained from July to December 2018. The research work was carried out using a five steps methodology which include; Intensive literature review, Site visits, Data collection, Data classification and analysis using payback period. Primary data used were collected through direct measurement of related parameters, The following findings were made; (1)That about 86 % ($5, 002, 391.844) of the total annual operating and maintenance cost goes into purchasing of natural gas for fuelling the turbines to generate electricity, (2) That the average daily gas flaring volume is about 7.2 mmscf/d (Million Standard Cubic Feet per Day) which translates into about 2,625 million mmscf per year, (3) Hitachi H25 gas turbine generator requires about 3.5657 mmscf of natural gas per day to generate 22.9 Mega Watts of electricity which translates into about 1,301 mmscf per year. The following are the recommendations;(1) That the federal government through its Department of Petroleum resource (DPR) should enforce a total ban on gas flaring in Nigeria, (2) That the federal government of Nigeria should decentralize electricity generation and distribution to encourage more investors through a competitive market system, (3) That more indigenous engineers and scientists should undertake researches in electricity generation, transmission and distribution so as to make the commodity available and affordable to Nigerian citizens in the nearest future.**

Keywords: **Utilizing, Benefits, Flared gases, Kokori, Hitachi. Affordable, available, power generation, translate.**

I. INTRODUCTION

Power generation system is an important aspect of electricity supply chain and it is crucial that enough electricity is generated at every moment to meet demand. Generating units will occasionally fail to operate most especially the turbine unit (Barabady and Kumar 2007).

Human existence and survival depends largely on the quality, quantity, availability and cost of energy. Energy is required for various industrial processes like heating steam, firing of furnace and petroleum refining process, metal working and manufacturing process, (Demirbaş, 2001). At the domestic; level different sources of energy are used for cooking, laundry, running TV sets, musical systems, lightings, boiling and space heating (Michael, 2017). Transportation of human beings, equipment, raw materials, finished goods from one place to another is solely dependent on energy which are in different forms, ranging from solar, liquid fossil fuel, compressed natural gas, coal, wind, thermal, hydro-dynamic energy and shale oil, Ahmed, Kamaruzzaman & Amer (2020).

Nigeria is endowed with vast oil and gas reserves and abundance of renewable energy potentials, yet the country is suffering an energy crisis, which has a major limitation on its ability to reduce poverty and achieve the Millennium Development Goals (MDGs) (Oyedepo, 2012).

Oil exploration activities in the Niger Delta region of Nigeria is causing environmental damage/pollution which have negative impact on the way of life and economies of the local inhabitants who earn living through fishing or agricultural farming, (Chijioke, Ebong & Henry 2018). Research reports show that about 142 million m^3 of gas was flared globally in 2020 mostly from the upstream petroleum sector (GGFR, 2020). The reasons why oil operators flare were highlighted by (Omontuemhen, et al., 2019; DiSavino, 2019; Ebrahim & Friedrichs, 2013).

The effects of natural gas flaring and petroleum spillages have also tainted the fish supply with toxins as well as the fruits and vegetables that are harvested from such polluted environment thereby taking toll on the health and well-being of the residents, (Ashton et al. 1999). The production of petroleum takes precedence over the interests of the local residents, their rights towards the alternatives of being gainfully employed in other sectors of the economy have been largely ignored, Alexander, Obinna & Ohaja (2016). The failure to respect property ownership rights can amount to problematic conflicts and subsequent losses, which is the case of Niger-Delta region of Nigeria (Sunday 2016). Figure 1. Shows picture of Gas flaring site in kokori Island, Delta State of Nigeria.

Figure 1. Gas flaring site in kokori Island, Delta State of Nigeria.

II. MATERIALS

i. Measuring tape
ii. Calculator
iii. Field note and pen
iv. Laptop
v. Microsoft excel software
vi. Hitachi H25 Gas turbine generator.

III. METHODOLOGY

This research work was carried out using a five steps methodology used by Adigio and Ohwofadjeke (2016) as follows;

i. Intensive literature search was carried out to identify and completely define areas of needs that necessitated this research.
ii. Site visits were made to carry out detailed investigation into the various sources of flared gases in the facilities.
iii. Data collection– Questionnaires, personal interviews of host community inhabitants and field visits were explored to gather data required for this research.
iv. Data classification and economic analysis using payback period.
v. Writing of research technical paper for publication.

The research methodology is illustrated in Figure 2.

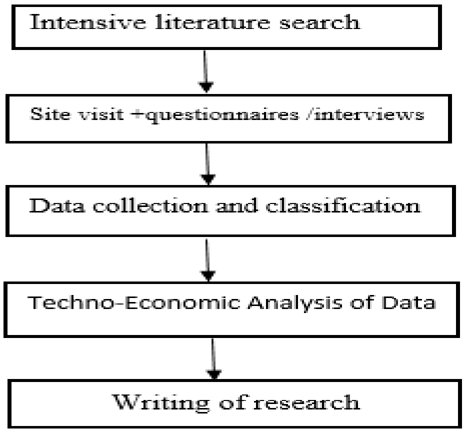

Figure .2 research Procedure Chart

IV. DATA COLLECTION

The primary data used for this research were collected through direct measurement of relevant parameters on site using appropriate tools and equipment. The site visits afforded the researcher opportunity to collect data on purchasing, installation, maintenance and running cost of gas turbine generator use for this research (Hitachi H25). Design documentation and other relevant literatures were also consulted to obtain required data.
Data collected was for a period of 12 months duration from January 2018 to December 2018.

V. BASIC ASSUMPTIONS

Reliability studies by Fernando et al, 2009 on gas to power plants asserted that gas turbines can operate to about 96 percent reliability (up time) with good maintenance culture and optimum operational conditions, this research will assume a 75 percent availability time throughout the year.
This implies that the plant will operate 24hrs per day and 274 days in a year. This is premised on the general knowledge that provided the facilities (flow stations/production facility) are up and running, there is associated gas evolved and made available to run the turbine. This 25 percent downtime will account for shutdowns on planned maintenance, facility shut down due to process upsets leading to unscheduled deferments.
75 percent of 365 days = 274 days.

- Power production capacity of 85 percent of H25 Hitachi gas turbine full power capacity. This gives 85 percent of 26.9MW = 22.839MW.
- The generated electricity is injected into the national grid for industrial application.
- The economic assessment is based on one unit of 26.9MWper turbine.
- Plant life span of 30years.
- Inflation rate is constant at 5%
- Discount rate of 10%

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- Nigeria corporate income tax of 30%
- A straight-line depreciation.
- Assume a salvage value of $500,000
- Processing cost of gas $3.75 per 1MMBTU (50% of EU import price for 2018)-

VI.ESTIMATED CAPITAL INVESTMENT (CAPEX)

CAPEXis the sum of all expenditure made in order to install the gas-powered plants. These include:

- ✓ Purchasing cost of the gas turbines and associated accessories.
- ✓ The cost of installation and commissioning.
- ✓ Cost of pipelines.

Table 1: Estimated initial Capital investment on Gas Turbine Generator procumbent and installation

SN	**Description**	**Cost ($)**	**Cost (₦ million)**
1	Purchase of gas turbine and other Equipment	8,000,000	2880000000
2	Piping and installation of equipment	1,000,000	360000000
3	Royalty to community	50,000	18000000
4	Cost of operation permit	500,000	180000000
5	Miscellaneous	1,000,000	360000000
	Total capital investment	**10,550,000**	3,798,000,000

US$ = ₦ 360 as time of research

VII. ESTIMATED OPERATION AND MAINTENANCE COST (OPEX)

The operational cost is the sum of all expenditures made to ensure smooth running of the plant daily. This comprises

- ✓ Maintenance
- ✓ Yearly Inspection (8000hours)(Combustion Inspection, Hot path gas inspection, Major Inspection)
- ✓ Materials and spares
- ✓ Salaries

Table 2: Estimated annual operating and maintenance cost of Hitachi H25 GTG

SN	**Description**	**Cost ($)**	**Cost (₦ million)**
1	Turbine maintenance	102,264.00	36815040
2	Fuel for plant maintenance	150,000.00	54000000
3	Spares and materials	140,000.00	50400000
4	Cost of fuelling GTG (natural Gas)	5,002,391.84	1800861062
5	Routines inspection cost	316,948.50	114101460
6	Miscellaneous and logistics	100,000.00	36000000
	Total capital investment	5,811,604.34	2,092,177,562

VIII. ESTIMATION OF FUEL CONSUMPTION FOR HITACHI H25 GTG

From field data collected the Hitachi H25 GTG consumes average of 3.5657 Million standard cubic feet (MMSCF) per day = 3,565,700 scf/day of natural gas.

The price of price of Natural gas in world market as at June 2019 (time of this analysis) is $4.33 per Thousand Cubic Feet.

1mmscf = 1000 x 1000scf

Hence; 3,565,700 scf = 35657 x 1000scf

If 1,000 scf costs $4.33

Then 3.5657 Thousand Cubic Feet will cost; 3565.7 x 4.33 = $15,439.481 per day

Hence; $15,439.481 x 324 = 5,002,391.844

IX. ANALYSIS OF FLARED GASES IN **KOKORI ISLAND OF DELTA STATE**

The field data collected shows that gas flaring around Eroike Community of Kokori Island is estimated at 7.3 Million standard cubic feet (MMSCF) per day Chromatographic analysis of the flared gas shows that it has 99.289% Methane composition.

The unit of thousand cubic foot is converted to kilogram

$$\left(16\frac{g}{mol}\right)x\left(1{,}000\frac{L}{m^3}\right)x22.4\left(\frac{L}{mol}\right) \quad [1]$$

Where; molar mass of methane (CH_4) = 16 g/mol

Since; Carbon (C) = 12.0107 Atomic weight & Hydrogen = 1.00794 Atomic weight

Hence; molar mass of methane = 12 + (1+1+1+1) = 16 g/mol

From the understanding of Avogadro's molar volume hypothesis; which states that the molar volume of a gas expresses the volume occupied by **1** mole of that respective gas under standard temperature and pressure conditions. Thus, at **STP** (Standard Temperature and Pressure) the volume of most common gases, is equal to **22.4 L** for 1 mole of **any ideal gas** atm. Here STP implies; temperature equal to **273.15 K** $\equiv 0°C$ and a pressure equal to **1.00.**

1ATM $\equiv$ 1.01325 bar respectively.

From Eqn.1;

We have 1000 scf $= 0.714\left(\frac{kg}{m^3}\right)$ [2]

From section IX above; 7300000 of gas is flared per day with 99.289% Methane components which implies that;

7300000 mmscf contains $\left(\frac{99.289}{100}\right)$ x 7300000 methane

= 7,248,097 scf methane $\equiv$ 7.248097mmscf of methane per day

It also follows that the flared gas contains

$\left(\frac{0.711}{100}\right)$x7300000 = 51,903 scf of trace elements $\equiv$ 0.051903 mmscf of trace elements per day inKokori Island.

This analysis can be extended to national scale using

Table 3: Average monthly fuel consumption versus power generated for July to December 2018 using Hitachi H25 GTG

Month	MMSCFHR	MMSCFD	Power (mW)
January	0.1479	3.6357	16.58
February	0.1515	3.6361	16.19
March	0.1485	3.6361	16.59
April	0.1365	3.5487	16.59
May	0.1479	3.6357	16.04
June	0.1485	3.6357	16.58
July	0.1471	3.53	16.1
August	0.1485	3.5642	16.04
September	0.1515	3.6361	16.59
October	0.1515	3.6357	16.58
November	0.1479	3.5487	16.19
December	0.1365	3.2754	14.96

X. ESTIMATED REVENUE FROM SALE OF ELECTRICITY GENERATED

The estimated revenue from sale of electricity from available document is as follows. Electricity in Nigeria is sold in KWH, hence the need to convert this turbine rating to KWH.

Converting Hitachi H25 gas turbine allowable running capacity of 22.865 MW to KW:

22.865 X 1000 = 22,865KW

Cost of electricity per KWh in Nigeria = $0.078 (NERC approved rate)

Therefore, the revenue from sales can be calculated using Eqn 3.

22,865 x 1 x 0.078 = $1783.47 (per hour of electricity delivered) [3]

Daily revenue will translate to -

1783.47 x 24 = $42, 803.28 (per day of electricity delivered).

Annual revenue per unit of 22.865MW turbine` = $42, 803.28 x 324 = $13,868,262.72(per year of electricity delivered). The annual electricity delivered is computed using 324 days, on the basis that the generator will require to be shut down for some days for maintenance and other inspections.

XI. FEASIBILITY ANALYSIS OF FLARE GAS TO POWER PROJECT

The Feasibility Analysis of Flare gas to power project was done using the payback period method as follows;

Payback period =

$$\frac{\text{total cost on investment}}{\text{total annual revenue from project}} \qquad [4]$$

Total cost on investment = initial capital investment on gas turbine generator procumbent and installation + Gas Turbine Generator routines inspection cost + Annual operating and maintenance cost of the facility

Let; PBP → payback period in years

ICIC → initial capital investment on gas turbine generator procumbent and installation = **$**10,550,000 (computed earlier in Table 1**)**

RIC → Gas Turbine Generator routines inspection cost = $316,948.50 (computed earlier in Table 2**)**

AOMC → Annual operating and maintenance cost of the facility = $6,636,256.32

TARFT → Total revenue generated from turbine

Hence; PBP = $\frac{ICIC + RIC + AOMC}{TARFT}$ = $\frac{17{,}503{,}204.82}{13{,}868{,}262.72}$ = 1.26 =

1.26 years ≡15 months (one year and three months)

The rule of thumb guiding determination of business feasibility using payback period method is that; businesses with payback period less than 3 years are accepted as been viable and most investors will want to invest their resource into such business ventures. This is because such investment can recover money spent on it within a reasonable length of time for its financiers.

XII. CONCLUSION

The following conclusions findings were made;

i. Hitachi H25 gas turbine generator requires about 3.5657 MMSCF of natural gas per day to generate 22.9 mW of electricity which translates into about 1,301 MMSCF per year.
ii. That the average daily gas flaring volume is about 7.2 mmscf/d which translates into about 2,625 MMSCF per year.
iii. The result of economic feasibility analysis of flare gas to power project carried in this research shows that it will take about 15 months to recover money spent on the project.
iv. That the about 86 % ($5,002,391.844) of the total annual operating and maintenance cost goes into purchasing natural gas for fuelling the turbines to generate electricity. Hence, converting the flare gases into electricity generation for Kokori Town of Delta State in Nigeria will reduce the high cost of fuelling the power turbines.
v. From environmental stand point; gas flaring has been proved to having a lot of negative effect on our natural environment, causing air, and water and soil pollution. In recent time, black soothe have become visible in most oil producing areas of the Niger Delta regions on Nigeria, with its attendant effect on human health.
vi. The Department of Petroleum resource (DPR) in its 2017 annual report, states that 11% of total gas production in Nigeria was flared that year, which translate into several billions of standard cubic feet of gases that could have been delivered to power plant.

XIII. RECOMMENDATION

From the findings of this research I wish to make the following recommendation;

- ✓ That the Federal government of Nigeria through its Department of Petroleum resource (DPR) should enforce a total barn on gas flaring in Nigeria.
- ✓ That the federal government of Nigeria should decentralize electricity generation and distribution to encourage more investors through a competitive market system.
- ✓ That more indigenous engineers and scientists should undertake researches in electricity generation, transmission and distribution so as to make the commodity available and affordable to Nigerian citizens in the nearest future.
- ✓ That the federal government of Nigeria should give electricity investors tax holiday and other incentives to encourage more investors to the power sector of our national economy.

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- Conarina School of Maritime & Transport Technology, Abraka as Lecturer I & Head of Marine Engineering Department.
- Niger-Delta Oil & Gas Training Institute Effurun, Delta State, as "Principal Marine Engineering Instructor".
- Victoria Works & Building Construction Nigeria Ltd, Enugu as "Maintenance Engineer".
- Ark Training Centre Port Harcourt as "Workshop manager".

In addition, he has a book titled "A Practical Approach to Piping Engineering & General Safety" and several technical papers in reputable peer reviewed international journals to his credit. His research interests include; Renewable Energy Improvements & Power Thermo-Fluids Systems Development, Design and Fabrication of Oil & Gas Equipment and Development of Low Cost Agricultural Equipment. Finally, Dr. Ogheneochuko has successfully participated in the design and execution of several complex and challenging engineering, Oil & Gas (both offshore and onshore) projects either as team leader or as team member. He speaks English, Urhobo, Essan and Edo languages fluently. He likes teaching, mentoring, research, reading and listening to music.

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