EVALUATION OF OPERATIONAL PERFORMANCE AND ECONOMIC ANALYSIS OF A GAS TURBINE POWER PLANT: A CASE STUDY OF IBOM POWER STATION

Abstract

This work studied the key performance indicators of Ibom Power Plant which is one of the Independent Power Producers (IPPs) in Nigeria. Ibom Power Plant consists of two GE Frame 6B and one Frame 9E turbine generators installed in a simple cycle configuration, using the conventional open cycle gas turbine (OCGT) technology. The data for the analysis of the plant was information contained in the Company monthly logbook. The average station load factor is about 42% and the average capacity utilization index is 51%, which is low compared with 70% encouraged by NERC. Also, the average generation utilisation index is 46% and the average plant heat rate is 12,659.60MJ/MWh, which is higher than the 10,000MJ/MWh allowed by NERC. The average thermal efficiency of the power plant is about 28.44% and the average capacity factor is about 19%. NERC's MYTO 2 tariff for generation companies of ₦10.70 per kWh was used in evaluating the company's revenue. Net present value (NPV) and internal rate of return (IRR) were employed in the economic analysis. It is obvious that the poor performance of the power plant led to low revenue generation by the company and the high cost of operation. At 20% discount rate recommended by NERC, the NPV was ₦-8255316354.00. The IRR showed that the company could break even at a discount rate of 4%. Cost of power generation can be reduced by improving capacity factor; running the power station at high load factor; increasing the efficiency of the power plant and proper maintenance plan to avoid breakdowns. An upward review of MYTO 2 tariff to ensure the economic viability of the Nigerian Electricity Supply Industry was recommended.

KEYWORDS: Operational performance**,** power plant**.**

I. INTRODUCTION

Energy is a critical part of every economy as it serves as the prime mover of the economy. To ensure a viable and sustainable development, reliable energy policy is needed. Energy and poverty reduction are not only closely connected to each other, but also with socioeconomic development, which involves productivity, income growth, education, and health (Nnaji et al, 2010). Electric power has become a fundamental necessity for the growth and well-being of all countries. Utilities, independent power producers (IPPs), industrials, and commercial customers around the world develop, own, and operate power plants to generate the electricity to meet their demands. Customers seek the most cost-effective and reliable power plant offerings to serve the power demands of their local grid or service territory (Mastrangelo, 2016).

Proper energy mix, consisting of renewable, nuclear in addition to fossil fuelled sources is a target of every nation in achieving her energy demands and meeting the stringent global emission requirement. One of the major reasons Nigeria is less attracted to start a new business or expand an existing business is unacceptable blackouts in a national grid which impact customers, particularly commercial and industrial users, almost causing them to go entirely off grid (Anosike *et al.,* 2017). The analysis of Nigeria's electricity supply problems and prospects found that the electricity demand in Nigeria far outstrips the supply, which is epileptic in nature (Oyedepo *et al.,* 2014).

Electricity is undoubtedly the most important energy source in the modern world; indeed electricity is what makes the world modern (Binsbergen et al., 2010; Boyce, 2001). All the facilities and devices that developed countries rely on electricity. At the same time, electricity is the most fleeting of all types of energy, so difficult to store that it must normally be consumed as soon as it is produced. This makes electricity both the most significant and also one of the most difficult products to understand economics (Agboola, 2011).

The cost of a unit of electricity depends on a large number of different factors. Key among these is the cost of the power plant in which it is produced (Breeze, 2010). This cost will be a compound of the basic installed or 'overnight' cost of the generating plant plus the cost of repayments on any loans taken out in order to finance construction of the plant. Once the plant begins operating there are operational and maintenance costs to take into account (Breeze, 2010). As with capital costs, these vary with the type of plant being considered. On top of this, there is also the cost of any fuel required by the plant in order to produce electricity. Fuel costs apply to fossil-fuel-fired plants, to nuclear power plants and biomass-fired plants but not to most renewable plants (APT, 2015).

The cost of a unit of electricity is determined by a combination of the costs associated with the production of the power and those associated with its delivery. The cost of each unit delivered can be broken down into elements reflecting the cost of each, plus the margin added at each stage to generate revenue and profit. Historical costs of electricity can be recorded and charted. However, businesses and economies are not interested in what they paid yesterday for electricity. What they generally need to know is what they are going to have to pay tomorrow. Equally, power generating companies and grid operators want to know what will be their least costly option for the generation and delivery of future power while governments may be seeking to frame their policies in order to ensure the future stability of supply.

In order for any of these aims to be achieved, the future cost of electricity must be predicted. This means that the energy supply system must be modelled. The complex nature of the electricity network makes this an extremely difficult task to achieve. However, various strategies have become established which allow future costs to be computed and investment decisions made. One of the most important means of handling this is the use of capital cost estimates of electricity.

Capital cost is important because it represents the amount that must be found at the outset to finance a power plant. In a liberalised electricity market where electricity companies must make a profit for their shareholders, the capital cost will often be a key factor in deciding what type of plant to invest in. The plant with the lowest capital cost will often appear the most attractive, even if the technology may not produce the cheapest electricity over the long term. The study will focus on the study of performance indicators and financial indicators of the Ibom Power Plant. The plant is an open cycle gas turbine power plant and hence no attempt will be made to study any other gas turbine configuration. The performance of other electricity sources (like hydroelectricity, wind turbine, steam turbine, etc.) will not be considered. The study will focus on the entire station rather than components of the plants. The expenditure will be treated as an aggregate of fuel costs, personnel costs, operation and maintenance costs. A NERC pricing model for electricity generation companies will be used to evaluate the net present value and internal rate of return. Also, the only available data contained in the company's logbook will be used in the analysis of this work. The information contained in the company's logbook covers only from October 2011 to March 2015; hence average estimates will be used for another part of the plant life.

II. MATERIAL AND METHODS

DATA COLLECTION

The data used in this work are secondary data. The information was collected from Ibom Power Plant. The Ibom Power Plant Project started off as a captive power plant which was to be part of a 100,000 barrel per day export refinery. Ibom Power Company (IPC) is one of the first independent power plants in Nigeria. IPC was incorporated on the 15th January 2001 by Akwa Ibom Investment and Industrial Promotion Council "AKIIPOC" under the Corporate Affairs Commission (CAC). The objective of the company is to enhance power generation in Nigeria through the existing national grid and eventually provide uninterrupted power to consumers in Akwa Ibom State and its environs. The Nigerian Electricity Regulatory Commission (NERC) required all power stations in Nigeria to keep up to date operation performance of their plants. The information used in this work was provided by the company in line with compliance to NERC regulations.

A. PLANT PERFORMANCE INDICATORS

Key Performance Indicators (KPIs) are important for monitoring the performance in the electricity generation industry. They can be used to identify poor performance and the improvement potential. KPIs can be defined for individual equipment, sub-processes, and the whole power plants. Different types of performances can be measured by KPIs, for example, energy generation, maintenance, control and operation. Performance measurement is a fundamental principle of management of power plants. The measurement of performance is important because it identifies current performance gaps between current and desired performance and provides an indication of progress towards closing the gaps. Carefully selected key performance indicators identify precisely where to take action to improve performance.

Load Factor

Load factor is an expression of how much energy used in a time period compared on how much energy that would have been used if the power had been left on during a peak period demand. It is the ratio of the average load to the maximum load for a certain period of time. Therefore, it is given as:

$$Load\ Factor = \frac{Average\ Load}{Maximum\ Load} \tag{1}$$

Plant or station load factor indicates the utilisation of the available capacity. It is the ratio of the output of power station to the rated capacity of the plant. It can be evaluated by the following relationship:

$$Plant\ Load\ Factor = \frac{Total\ Energy\ Generated}{Installed\ Quantity} \tag{2}$$

The installed quantity is the product of available capacity and the hours of the reporting period.

Utilisation Indices

Utilisation factor for a plant depends on the use to which the plant is put. A low utilisation factor means that the plant is either standby or has been installed to take into account the future increase in the load. It is the ratio of the maximum generation to the plant installed capacity. It is given as:

$$Utilisation\ Factor = \frac{Maximum\ Load}{Installed\ Capacity} \tag{3}$$

Capacity utilisation index is the ratio of the available capacity to the installed capacity for the power plant. Capacity utilisation index can be expressed mathematically as:

$$Capacity\ Utilization\ Index = \frac{Avaiable\ Capacity}{Installed\ Capacity} \tag{4}$$

Generation utilization index is the ratio of average actual generation to the available capacity of the plant and it is expressed as:

$$Generation\ Utilization\ Index = \frac{Average\ Actual\ Generation}{Available\ Capacity} \tag{5}$$

Capacity Factor

Plant use factor is the ratio of energy produced in a given time to the maximum possible energy that could have been produced during the actual number of hours the plant was in operation. Mathematically, it is expressed as:

$$Plant\ Use\ Factor = \frac{Total\ Energy\ Generated}{Installed\ Capacity \times Total\ Operating\ Hours} \qquad (6)$$

The capital cost of a power plant refers to the cost to install one megawatt of generating capacity. The generating capacity referred to the rated capacity of the plant (often called its nameplate). However, in most cases, a power station will not be able to produce power at its rated capacity continuously. The capacity factor is a figure which takes account of this discrepancy between nameplate capacity and actual output (Breeze, 2010). The capacity factor of a power plant is the ratio of its actual output over a period of time, to its potential output if it were possible for it to operate at full nameplate capacity indefinitely. It varies greatly depending on the type of fuel that is used and the design of the plant. Plant capacity factor is evaluated as the ratio of the total energy the power plant produced to the amount of energy the plant would have produced at full capacity and expressed as:

$$Plant\ Capacity\ Factor = \frac{Total\ Energy\ Generated}{Installed\ Capacity \times Total\ Hours\ of\ the\ Year} \qquad (7)$$

Plant Efficiency

Heat rate refers to energy conversion efficiency, in terms of "how much energy must be expended in order to obtain a unit of useful work. The primary metric of unit efficiency used in the power industry is the heart rate of the unit, which is a ratio of the energy required to produce a unit of electricity – such as how many MJ/s of fossil fuel are required to produce 1kW of electricity at the generator terminal. Heat rate is expressed mathematically as:

$$v = \frac{Volume\ of\ Gas\ Consumed \times Calorific\ Value\ of\ Gas}{Total\ Energy\ Generated} \qquad (8)$$

Energy efficiency is closely related to the 'heat rate'. Heat rate is the quantity of heat required to produce one unit of useful output and therefore a lower heat rate is more efficient and gives higher percentage energy efficiency. The relationship most frequently used to describe heat rate and efficiency in respect of electrical power generation is the thermal efficiency of the plant in terms of energy conversion and it is given as:

$$\eta_{th} = \frac{3600}{v} \qquad (9)$$

In order to analyze the viability and the financial risk of operating generation power plants in Nigeria, it is indispensable to precisely identify which are the main parameters that influence their viability so that they can measure the impacts on the financial return. The financial analysis of power generation projects is also necessary due to many other factors, such as the characteristic of strong mobilization of capital: "sunk costs". That is, the implementation costs will not have another destination different from the one that was initially planned.

$$Generation\ Unit\ Cost = \frac{Total\ Expenditure}{Total\ Energy\ Generated} \qquad (10)$$

$$Fuel\ Cost = Power\ Ouput \times Hours\ per\ Year \times O\&M\ Cost\ per\ MWh \qquad (11)$$

O & M means operation and maintenance.

$$Revenue = Power\ Output \times Hours\ per\ Year \times Price\ of\ Electricity \qquad (12)$$

B. ECONOMICS OF THE POWER PLANTS

Electricity is the most important energy source in the modern age but also the most ephemeral, a source that must be consumed as fast as it is produced. This makes modelling the economics of electricity production more complex than carrying out the same exercise for other products. Accurate modelling is important because it forms the basis for future investment decisions (Breeze, 2010). In the electricity sector two fundamental yardsticks are used for cost comparison, capital cost and the levelized cost of electricity. The latter is a lifecycle cost analysis of a power plant that uses assumptions about the future value of money to convert all future costs and revenues into current prices. This model is widely used in the power industry but has some significant failings, particularly in its ability to handle risk. Capital cost model developed by NERC will be used in this work (Breeze, 2010).

The generation cost of power plant is price required over the plant life to cover all the cost components as follows: capital cost, fuel cost, tax, transmission costs, return on capital, operating and maintenance cost both fixed and variable (with appropriate costs components escalated). These together with other factors to include capacitor factor, thermal efficiency (heat rate), plant internal energy use (auxiliary requirement) and availability form the input parameters for the NERC financial model. The unit cost of energy generated is refined by calculating a price that makes the net present value of the power station equal to zero.

The model capital cost is calculated as weighted average cost of capital (WACC) (equations 14-16), using the capital asset pricing model (CAPM). This is proposed to provide a return on existing assets and appropriate incentives for future investment. This financial model was developed in line with the weighted average cost of capital (WACC*) computed as Brealey and Meyers (2003)

$$WACC^{*} = D \times kd \times (1 - t) + E \times ke \qquad (13)$$

D is the percentage of debt on the total capital, Kd is the cost of debt, t is the marginal corporate tax rate, E is the percentage of equity on the total capital and Ke is the cost of equity.

The NERC financial model is given as (Amadi & Andzenge, 2012)

$$\mathrm{WACC} = \mathrm{R_d} \times \mathrm{D}/(\mathrm{D}+\mathrm{E}) + \mathrm{R_e} \times \mathrm{E}/(\mathrm{D}+\mathrm{E}) \qquad (14)$$

In which R_e is the nominal cost of equity; D is the total market value of debt; E is the total market value of equity and R_d is the nominal cost of debt, given as (Anosike et al., 2017)

$$\mathrm{R_d} = \mathrm{R_f} + \mathrm{DRP} + \mathrm{IC} \qquad (15)$$

DRP is the debt risk premium; IC is the debt issuance cost lending in Nigeria; and R_f is the risk-free rate observed in the market. Equations 14 and 15 calculate weighted average of capital (WACC) without tax and return on equity respectively.

$$\mathrm{R_e} = \mathrm{R_f} + \text{ße}(\mathrm{R_m} - \mathrm{R_f}) \qquad (16)$$

Re is the return on equity; ße is the correlation between the equity risk and overall market risk; R_m is the return on the market portfolio; and $(R_m - R_f)$ is the market risk premium.

The nominal post tax WACC and real pre-tax WACC are calculated with equation (17) and (18) respectively (Anosike *et al.*, 2017).

$$\text{Nominal post tax WACC (w)} = \mathrm{R_e} \times \frac{\mathrm{E}}{\mathrm{V}} + \mathrm{R_d} \times (1 - \mathrm{T_e}) \times \frac{\mathrm{D}}{\mathrm{V}} \qquad (18)$$

$$\text{Real pre tax WACC (RW)} = [(1 + (\mathrm{w}/((1 - \mathrm{T_c}))/(1 + \mathrm{i})] - 1 \qquad (19)$$

V is the total market value of the business, i.e. debt plus equity; T_c is the company tax rate; and i is the inflation rate.

Net Present Value

The investment analysis is a process that evaluates a diversity of alternatives and that decides which the best option is. In order to manage the financing of enough creditors that assures the creation of a project, in a way that they will be convinced of investing, it is necessary to prove the economic-financial viability of the enterprise and its ability for ensuring the credit for the payment of the financing debt. Besides, the investors need to be familiar with the economic and technical characteristic of the project and with the risks involved in it, so that the financial return is enough to compensate for the risks taken.

Economic evaluation of a power plant can be explored in a number of ways. All methods account for the cost of a decision over time. There are several accepted methods to examine cost over time. A common approach is to evaluate net present value (NPV). The net present value method looks at the value of the project over time by converting all income and expenditures into equivalent values at the current time and subtracting the initial investment. To do this, the future interest rate and the rate of inflation must be estimated and expressed as a discount rate, r.

$$NPV = \sum_{t=1}^{n} \frac{cash\ flow}{(1+r)^{t}} - CF_o \qquad (20)$$

CF_o is an initial investment, r is discount rate, t is time and cash flow is income minus expenses.

The economic viability of an enterprise can be verified when the expected Net Present Value (NPV) of future net worth cash flows are higher than the expected costs of the investment, that is, when the NPV of the projects is positive.

Internal Rate Return

The results based on the calculations using the net present value and the rate of return are often competing in the technical literature of investment-profitability calculations. Decisions are usually made based on excess profits above the rate of return requirements calculated by the net present value principle, especially in cases showing the dominance of financial approach (|Lajos, 2011). Internal rate of return (IRR) is the interest rate at which the net present value of all the cash flows (both positive and negative) from a project or investment equal zero. The internal rate of return is used to evaluate the attractiveness of a project or investment. The internal rate of return (IRR) is a rate of return used in capital budgeting to measure and compare the profitability of investments. It measures the investment yield of power plant.

To evaluate IRR, an attempt is made to set the discount rate of NPV to zero. If the NPVs of a project were at different discount rates and the resulting values are positive and negative, then the IRR will be given as:

$$IRR = a + \frac{NPV_a}{NPV_a - NPV_b} \times (b - a) \qquad (21)$$

NPV_a is the associated with the smaller discount rate, a; and NPV_b is the NPV associated with the bigger discount rate, b.

III. RESULTS AND DISCUSSIONS

A. PLANT KEY PERFORMANCE INDICATORS

Performance measurement is a fundamental principle of management. The measurement of performance is important because it identifies performance gaps between actual and desired performance and provides an indication of progress towards closing the gaps. Performance of Generating Plant has been at the forefront of monitoring and evaluating the interaction between the numerous market drivers to assess their impact on the operation of the power plant. Power plant operators are in charge to keep up efficiency under continuously changing loads. Power plant managers strive for meaningful figures for strategic decisions. The plant key performance indicators presented evaluate the deviations between actual and expected performance. The results of the plant key performance indicators are presented in figure 1.

Plant Load Factor

Plant load factor determines the exact loadability of the power plant (Motghare and Chan, 2015). It compares the total energy generated in the light of the available capacity. It focuses on the available capacity rather than installed capacity. High plant load factor indicates good plant performance. Figure 1 shows that the highest load factor for the Ibom Power Plant is 87% occurring in December 2011 and December 2014 and the plant recorded a good generation utilization index in both months. As a matter of fact, the highest generation utilization index of 92% occurred in December 2014. Therefore, a high load factor will lead to better plant performance as the plant will not be available but will be generating power at or close to available capacity. A higher load factor means more output from the power plant.

Also, the power plant recorded a zero percent load factor between March 2013 and July 2013 as shown in figure 1. During the period, the plant was generating no power as a result of plant failure. The plant was out of operation until December 2013 when power generation commenced again. The plant incurred costs due to repairs and unplanned maintenance during that period. It is important to note that the abrupt irregular shape of the plot of figure 1 is as a result of incessant plant unavailability and failures.

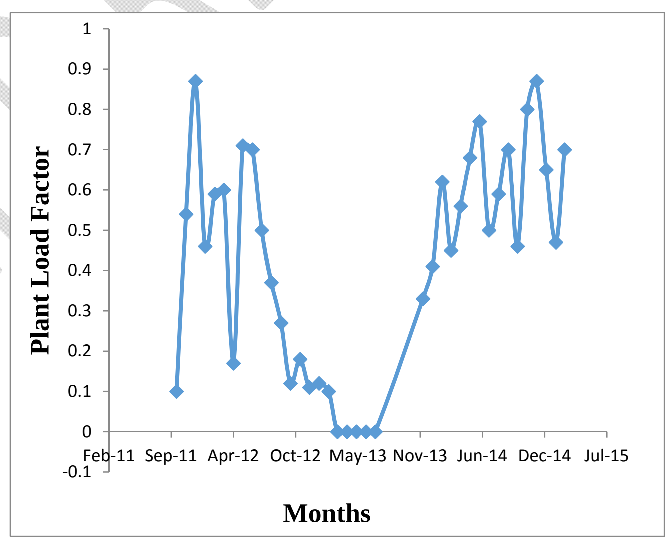

Figure 1: Plant Load Factor for the power plant

Plant Utilization Indices

The utilization factor is the ratio of the time that a piece of equipment is in use to the total time that it could be in use. It is often averaged over time in the definition such that the ratio becomes the amount of energy used divided by the maximum possible to be used. Utilization factor is the ratio of the maximum load which could be drawn to the rated capacity of the system. It measures the extent or level to which the productive capacity of a plant is being used in generation of energy. Expressed usually as a percentage, it is computed by dividing the total capacity with the portion being utilized. The capacity utilization rate affects earnings for power utilities (Lu, 2017).

The Capacity utilization index for the power station is shown in figure 2. It ranged from 39% to 61%, when the plant is in operation; although, 80% shoot up was observed in October, 2011 when the plant started power generation. The station operated mostly at 61% capacity utilization index as observed in figure 2, this is below 70% capacity utilization index allowed by MYTO (NERC, 2010). Also, figure 3 showed generation utilization index for the power station. It ranged from 10% to 92%. The least generation utilization of 10% occurred in February, 2013 and the highest generation index of 92% occurred in December, 2014. Generation utilization index has no direct

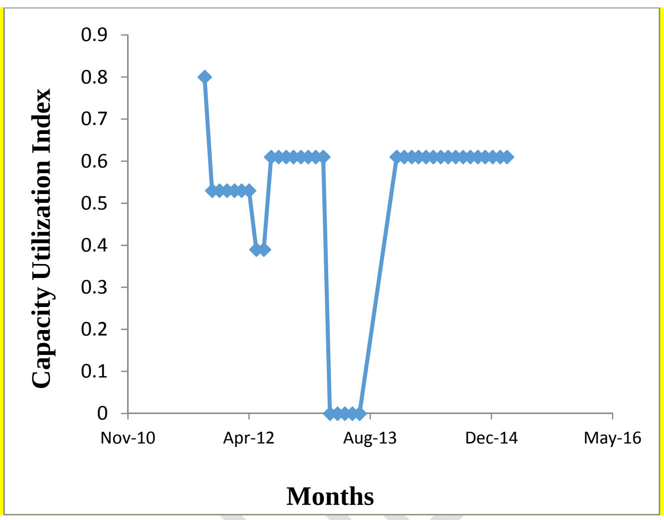

Figure 2: Capacity Utilization Index for the power plant

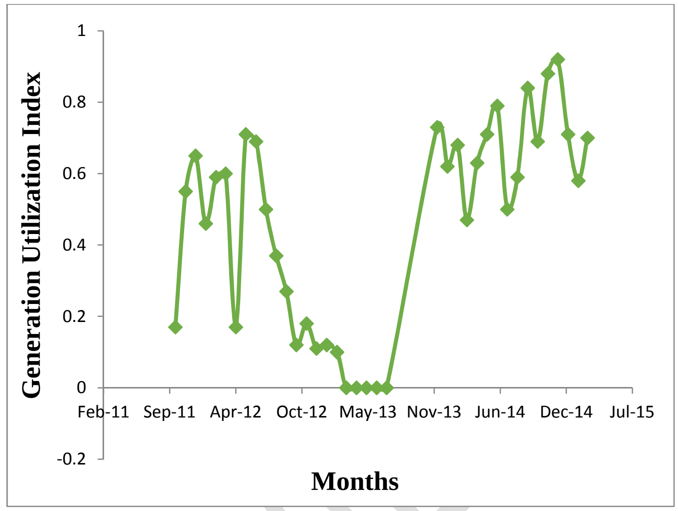

Figure 3: Generation Utilization Index for the power plant

relationship with capacity utilisation index as can be seen from figures 2 and 3. Generation utilisation index compares the average actual generation to the available capacity of the power station. High value indicates better station performance and plant operators should strive to achieve high capacity utilisation index to reduce redundancy of generators and boost greater energy generation. This will invariably increase the revenue of the power station and ensure improved power supply to customers.

Plant Capacity Factor

Plant capacity entails both the total amount of power (MW) and energy (MWh) that a plant is capable of producing. The Ibom Power Plant is capable of producing 115MW of power and energy of about 1,007,400MWh in year. Although the installed capacity is 190MW, only 115MW is the maximum available capacity of the plant all through the reporting period.

Plant capacity factor is the ratio of the average output of the plant for a given period of time to the plant installed capacity. The average output of a plant may be obtained for any time period, like a day, a week, a month or a year. The plant capacity factor indicates the extent of use of the plant in generating energy. High capacity factor signifies that the average energy generation of the plant is high while the low capacity factor indicates low average energy generation.

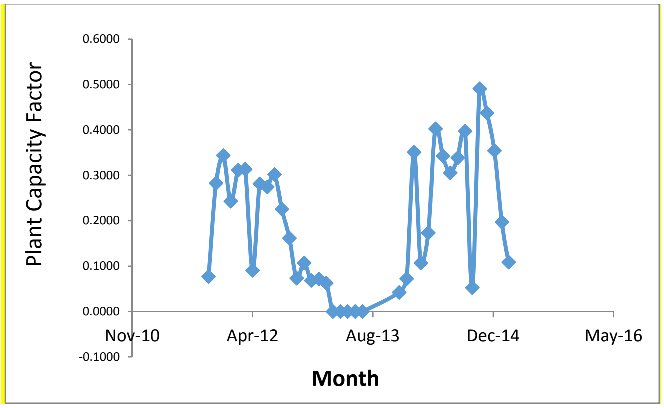

Figure 4: Monthly Plant Capacity Factor for the plant

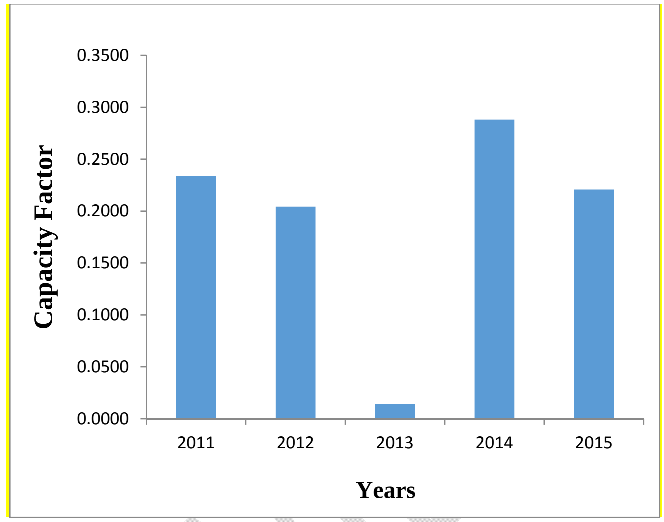

Figure 5: Yearly Capacity Factor for the Powerplant

Figures 4 and 5 showed the monthly and yearly plant capacity factors for the power plant respectively. Figure 4 showed that November, 2014 had the highest monthly plant capacity factor of 49% with a total energy generation of 67,169MWh, while the lowest monthly plant capacity factor of only 4% was recorded in December 2013 with a total energy generation of 5,943MWh. It is important to note that from March 2013 and November 2013, the station was not in operation and therefore plant capacity factor for that period was zero. Figure 4 and 5 showed that the station recorded the highest yearly plant capacity factor of about 29% with a total annual energy generation of 479,453MWh; this is very low when compared with 1,007,400MWh expected to be generated by the station's available capacity. The station recorded the lowest annual plant capacity factor of about 1.45% with total annual energy generation of 24,098MWh in 2013. This is because the plant was not in operation for six months in 2013.

Plants are meant to produce at 100% capacity factor; but, there are several reasons why a plant would have a capacity factor lower than 100%. The first reason is that it was out of service or operating at reduced output for part of the time due to equipment failures or routine maintenance. This accounts for most of the unused capacity of base load power plants. Base load plants have the lowest costs per unit of electricity because they are designed for maximum efficiency and are operated continuously at high output. Geothermal plants, nuclear plants, coal plants and bioenergy plants that burn solid material are almost always operated as baseload plants.

The second reason that a plant would have a capacity factor lower than 100% is that output is curtailed because the electricity is not needed or because the price of electricity is too low to make production economical. This accounts for most of the unused capacity of peaking power plants. Peaking plants may operate for only a few hours per year or up to several hours per day. Their electricity is relatively expensive. It is uneconomical, even wasteful, to make a peaking power plant as efficient as a base load plant because they do not operate enough to pay for the extra equipment cost, and perhaps not enough to offset the embodied energy of the additional components. The major reason for low capacity factor of Ibom Power Plant is due to equipment failures and prolonged maintenance period.

Plant Heat Rate

Heat rate indicates how much heat is used for the generation of one unit of electricity. The thermal efficiency of electricity production is represented by the heat rate, which measures the amount of energy used to generate one kilowatthour of electricity. A generating unit with a lower, or more efficient, heat rate can generate the same quantity of electricity while consuming less fuel, compared with a unit with a higher heat rate. Lower fuel use per unit of electricity generated also reduces the corresponding emissions of pollutants such as sulfur dioxide (SO_2), nitrogen oxide (NO_X), mercury (Hg), and carbon dioxide (CO_2). Consequently, improving heat rates at power plants can lower fuel costs and help achieve compliance with environmental regulations.

The heat rate of a conventional fossil-fueled power plant is a measure of how efficiently it converts the chemical energy contained in the fuel into electrical energy. This conversion is accomplished in four major steps. First, the chemical energy in the fue1 is converted into thermal energy, then the thermal energy is converted into kinetic energy, then the kinetic energy is converted in mechanical energy, and lastly, the mechanical energy is converted to electrical energy. In each of these sub-processes, some energy is lost to the environment. Some of the fuel is not burned completely; some of the thermal energy is lost out the stack and some of the kinetic and mechanical energy produces heat instead of electricity. The heat rate of a power plant is the amount of chemical energy that must be supplied to produce one unit of electrical energy. Put another way, it is the required input divided by the desired output, or the reciprocal of the efficiency. If a power plant converted 100% of the chemical energy in the fuel into electricity, the plant would have a heat rate of 36MJ/MWh.

The MYTO allows for a heat rate of 10,000MJ/MWh (NERC, 2010). The power stations that have their heat rate above the MYTO allowed value need to improve on their efficiency. It can be seen from figure 6, that the heat rate for the months during the reporting period were above the allowed value of 10,000MJ/MWh. It means that the conversion efficiency of the plant is not acceptable and good quantity of the chemical energy contained in the fuel is wasted.

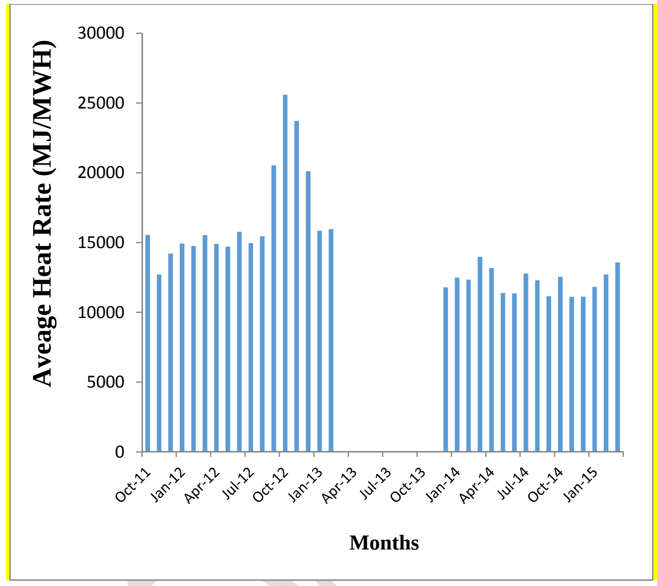

Figure 6: Average Heat Rate of the Power Plant

B. ECONOMICS OF THE POWER PLANT

While economic models may be used to predict the cost of electricity with varying degrees of confidence, the only way those predictions can be judged is by looking at historical costs and trends. Historical precedent can be used to predict what will happen in the future; much future behaviour will follow patterns already established in the past. Historical electricity costs and cost trends from different regions will often highlight differences in the way an electricity market is regulated as well as providing evidence of subsidies. The values were in determining net present value and internal rate of return

Figure 7 presented the total monthly energy generated by the power plant. It can be seen that the plant generated 67,169MWh of energy in November 2014. This is the highest energy generated by the plant during the period under review; and the highest revenue per month was realized in the same month to the tone of (₦718, 708,300.00) Seven Hundred and Eighteen Million, Seven Hundred and Eight Thousand, and Three Hundred Naira. As expected the highest cash flow of about (₦311, 543,926.42) Three Hundred and Eleven Million, Five Hundred and Forty Three Thousand, Nine Hundred and Twenty Six Naira, and Forty Two Kobo were realised in the month.

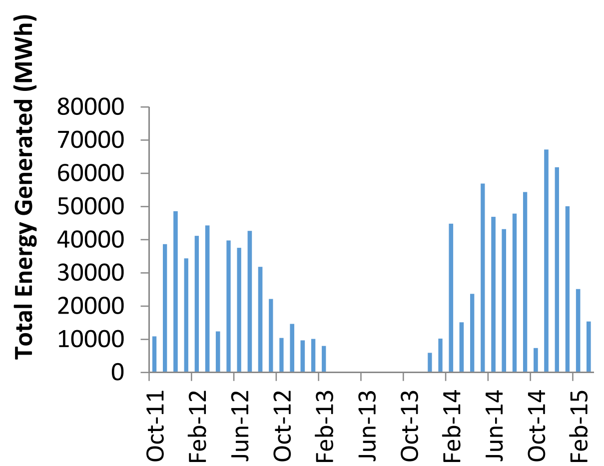

Figure 7: Monthly Total Energy Generated by the plant

The plant was not in operation from March 2013 to November 2013, and hence no energy was generated and consequently, no revenue was realized within that period. Nevertheless, a substantial amount of money was spent in repairs and maintenance during that period. The plant generated lowest energy per month of about 5,943MWh in December 2013 and the associated revenue per month was (N63, 590,100.00) Sixty Three Million, Five Hundred and Ninety Thousand and One Hundred Naira.

Evaluation of the Net Present Value

One of the key measures used to assess the financial viability of the power plant project is the Net Present Value (NPV). If the NPV is positive the project is economically viable. The relationship for NPV is given in equation 20. The revenue was evaluated using equation 12 and the price for electricity used was N10.70/kWh as recommended by MYTO 2. Discount rate of 20% as recommended by MYTO 2 was also used in the evaluation of the NPV. The expected life of gas turbine is usually twenty years and hence twenty year was used in the analysis as the lifetime of the gas turbine. The initial investment is 90 million US dollars (Group Five, 2005) and it is estimated to be ₦12060000000 (Twelve Billion, Sixty Million Naira) when multiply with the prevailing exchange rate as at the time of awarding the contract (CBN, 2005). The average value for revenue for the year under study was to estimate the revenue for the remaining life of the gas turbine. The NPVs for discount rates of 20% and 1% are presented in figures 3 and 4 respectively.

Evaluation of the Internal Rate of Return

Internal Rate of Return (IRR) is the break-even interest rate which equates the present worth of a project's cash outflows to the present worth of its cash inflows. It helps us to determine the discount rate at which project can break even. In order words, all expenditures including initial investment will be equal to revenue at this discount rate. The NPVs at 20% and 1% discount rate were the upper and lower bounds respectively. Since NPV at 20% is negative and that at 1% is positive; therefore, there is a discount rate between the two at which the NPV will be zero. Using equation 21, the IRR is 4%. Hence, Ibom power plant will break even if it operates at discount rate of 4%; and for the company to make profit, the NERC recommended discount rate should less than 4%.

Nevertheless, discount rate of 4% seemed impractical in the present economic reality, hence there a need for the price of electricity discharged by the generation companies in Nigeria to be reviewed upward. This will help electricity generation companies to recoup their investments and make substantial profits. It will also make the Nigerian electricity supply industry attractive to both local and foreign investors. The ultimate result will be improved steady power supply that will lead to a better standard of living and robust economic and social activities.

IV CONCLUSION

The key performance indicators of Ibom power plant have been studied. It was observed that the power plant is operating below capacity. The average station load factor is about 42% and the average capacity utilization index is 51%, which is low compared with 70% encouraged by NERC, 2010. Also, average generation utilization index is 46% and the average plant heat rate is 12,659.60MJ/MWh, which is higher than the 10,000MJ/MWh allowed by NERC, 2010. It is important to note that a lower heat rate is desirable as it leads to better thermal efficiency. The average thermal efficiency of the power plant is about 28.44% and the average capacity factor is about 19%. It is obvious that this poor performance of the power plant led to low revenue generation by the company and higher cost of operation. Cost of power generation can be reduced by selecting equipment of longer life and proper capacity; running the power station at high load factor; increasing the efficiency of the power plant and proper maintenance plan to avoid breakdowns. This will reduce the operation and maintenance costs for the power plant and increase revenue for the generation company.

Also, the discount rate of 20% assumed by NERC in proposing the price of electricity for generation companies is high. At that discount rate and electricity price of ₦10.70 per kWh, the generation companies will hardly break even. A better electricity price and a lower discount rate will not only improve the revenue for the electricity generation companies but will also attract more investors to the Nigerian Electricity Supply Industry.

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