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# APPRAISAL OF POWER GENERATION CAPABILITY OF IBOM POWER STATION

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**Abstract**

*This research paper evaluates the power generation capability of Ibom Power Station – a gas thermal station in Nigeria with total installed capacity of 190 MW. The performance indices (capacity factor, use factor, utilization factor, and availability factor) assessed showed that the power station obviously operates well below installed capacity. The study further reveals that 42.48% of the installed capacity was available. The utilization and use factor ranged from 46.50% to 92.46% for the period reviewed. Also the heat rate of the plant was obtained. An empirical model was developed to predict the monthly power generation of the power station to enable the management of the power station and the National Control Centre (NCC) plan effectively for inventory and production. It was also observed that the power station does not aim to operate at full capacity rather to meet with the demand of the NCC.*

**Keywords:** Energy, Power plant factor, Efficiency, Gas Turbine, Power Generation, Performance.

## 1.1 Introduction

Energy has a major impact on every of our socio-economic life. It plays a vital role in the economic, social and political development of our nation. Inadequate supply of energy restricts socio-economic activities, limits economic growth and adversely affects the quality of life. Improvements in standards of living are manifested in increased food production, increased industrial output, the provision of efficient transportation, adequate shelter, healthcare, and other social amenities. These will require increased energy consumption. Thus, our future energy requirements will continue to grow with the increase in living standards, industrialization and a host of other socio-economic factors (ECN, 2003). Uninterrupted power supply is a vital issue for all countries today. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible, and environmentally friendly. Security, climate change, and public health are closely interrelated with energy (Ramchandra, 2011).Conversely; a lack of access to energy contributes to poverty and deprivation and can contribute to economic decline. Energy and poverty reduction are not only closely connected to each other, but also with the socio-economic development, which involves productivity, income growth, education, and health (Nnaji et al, 2010).

Nigeria is blessed with abundant primary energy resources. These include reserves of crude oil and natural gas, coal, tar sand, and renewable energy resources such as hydro, fuel wood, solar, wind, and biomass. Though, solar energy presents promise of becoming a dependable energy source for future (Dara et al, 2013), the utilization of turbine power plant fired by natural gas remain the most viable option in Nigeria at present. The level of energy utilization in an economy, coupled with the efficiency of conversion of energy resources to useful energy, is directly indicative of the level of development of the country's economy. The percentage contribution of energy to Federation account, GDP at 1990 and Export earnings as of 2004 stood respectively at 79%, 32.6%, and 96% (Sambo, 2008); this point to the fact that the energy sector has a major role to play in nation's economy.Nigeria's chance to raise the standard of living of its citizens and stabilize its social, economic and political systems lies in its commitment to increase energy output and utilization starting at the grassroots level (Oyedepo, 2012).

Reliable power supply contributes to an enabling environment for industrialization. Energy shortage may sound paradoxical in a major oil-producing nation as Nigeria. The Nigerian energy industry is probably one of the most inefficient in meeting the needs of its customers (Iwayemi, 2008). However, acute energy shortages for many years in this country have led to perennial and regular electric power outages, with serious consequences on economic development, citizen safety and the quality of life for its people.( Eleri et al, 2012) reported that the economic loss associated with self-generation of electricity is high compared to an average tariff charged by the distribution companies. An 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. The erratic electricity supply hinders the country's development and not only restricts socio-economic activities but affects adversely the quality of life (Sule et al, 2011).

In this regard, power plants play a key role in producing electricity. Among different type of power plants, gas turbines have gained a lot of attention because they are attractive in power generation field due to feature low capital cost to power ratio, high flexibility, high reliability

without complexity, compactness, early commissioning and commercial operation, and fast starting-accelerating and quick shutdown (Oyedepo et al, 2014). Gas turbines can be started and stopped easily which make them every useful at peak period in energy demand. Gas turbines are now being used for electricity generation in Nigeria because of the availability and low prices of natural gas in the country (Abam et al, 2012). In a bid to improve the electricity generation in Nigeria, the Electric Power Sector Reform (EPSR) Act has made it possible for Independent Power Producers (IPPs) to obtain license from the National Electricity Regulatory Commission (NERC) to generate electricity. The involvement of IPPs in power generation in Nigeria is expected to create efficient, transparent and goal driven institutions that can achieve the desired performance expected from a power industry as obtainable in the developed countries (Agoola,2011).
Researches have been reported on the performance of thermal plants in Nigeria such as (Melodi, A.O.et al. 2011) (Oyedepo, S.O., 2012) (Oyedepo, S.O. et al.2014) but this research is unique in its own as it does not just evaluate the performance of the IPP under study, it also tries to predict to an acceptable level, the monthly power generation of the power station in a bid to aid in the proper management of the plant to improve electric power generation in Ibom Power Company with the hope of likewise improvement in the electric power generation in the country at large

**Ibom Power Company**

The Ibom Power Company Ltd. is an IPP (Independent Power Producer) established in Ikot Abasi, Akwa Ibom State of Nigeria. It is owned by the AkwaIbom State government who also manages it. The 190MW power station has been operational since December 2009. It consists of three (3) General Electric (GE) gas turbines (one Frame 9, two Frame 6) which are connected to the national grid separately via 11/132 KVA transformers. The turbines operate on only natural gas as driving fuel. The essential components of the gas turbine power plant are the compressor, combustion chamber (CC), the turbine, and the generator. A schematic diagram of a simple gas turbine (as used in the power station) is shown in Figure 1. The fresh atmospheric air is drawn into the circuit continuously at atmospheric pressure and temperature at point 1. This air is further compressed by the compressor with compression ratio of about 9:1 then the compressed air enters the combustion chamber at point 2. Fuel is injected to the combustion chamber and energy is added by the combustion of the fuel in the air. The products of combustion are expanded through the turbine which produces the work and finally discharges exhaust fumes to the atmosphere.

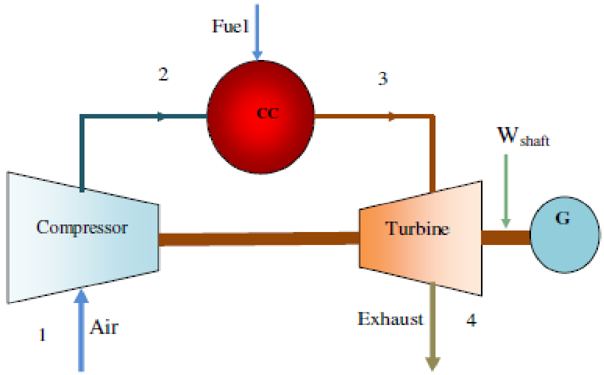


**Figure 1:** Schematic diagram of a simple gas turbine

## 2.0 Material and methods

## 2.1 Data Collection

Data used for this study were collected from the power stations considered. During collection of data from these stations, efforts were made to ensure that the data collected were true representations of the case study. Several industrial visits were made to the power station to gather information about its power generation process, plant layout, and operational statistics.

### 2.2 Methodology

The performance of the power plant was evaluated based on the plant factors (availability, load, capacity, and use factors), thermal efficiency, heat rate (energy efficiency), and economic efficiency. These were calculated on a monthly basis. The monthly power generation capability (in MW) of the power station was predicted using regression analysis.

### 2.2.1 Plant Factors

The plant factors were calculated using equation (1), (2), (3), and (4).

$$\text{Load Factor} = \frac{\text{Average Power Generated in a given period}}{\text{Maximum (peak)load generated in the same period}} \quad (1)$$

$$\text{Capacity Factor} = \frac{Total\ energy\ generated}{Installed\ capacity \times total\ hours\ in\ the\ period} \quad (2)$$

$$\text{Utilization Factor} = \frac{\text{Maximum generated load in a period}}{\text{Installed capacity}} \quad (3)$$

$$\text{Use Factor} = \frac{Power\ generated\ in\ a\ given\ period}{Installed\ capacity \times operating\ hours} \quad (4)$$

### 2.2.2 Heat Rate (Energy Efficiency)

Heat rate ($\vartheta$) is given as:

$$\vartheta = \frac{Heat\ supplied\ in\ a\ period\ (MJ)}{Energy\ output\ in\ the\ period\ (MWh)} \quad (5)$$

2.2.3 Thermal Efficiency

Thermal efficiency, $\eta_{th} = \frac{3412.75}{\vartheta}$ (6)

Where $\vartheta$ = heat rate in MJ/MWh

2.2.4 Economic Efficiency

The economic efficiency of the power station can be evaluated with its generation unit cost and fuel unit cost. They are calculated with equations (7) and (8) respectively.

$$\Phi = \frac{C}{E} \quad (7)$$

$$FUC = \frac{cost\ of\ fuel\ used\ in\ a\ period\ (\text{N})}{power\ produced\ in\ that\ period\ (MWh)} \quad (8)$$

Where:

$\Phi$ = generation unit cost (N/MWh)

C = production cost for a period (N)

E = energy produced by the power plant in the period (MWh)

FUC = fuel unit cost (N/MWh)

2.2.5 Linear Regression

The study showed that there are basic management factors that affect energy generation. These factors include: Gas volume utilization, maintenance index and costs. These factors are used to predict the response, monthly power generated. To determine if there exists a relationship between the independent variables and the dependent variable or response, the data collected was subjected to regression analysis using the regression tool of Minitab 17. Regression analysis was carried out on the data using Minitab 17 to yield a model to predict the monthly power generation.

**3.0 Results and Discussions**

The plant's capacity factor for the period under review is presented in Figure 2. The average capacity factor of the plant is 28.01% with a minimum value of 5.23% in October, 2014 and a maximum value of 49.10% in November, 2014 compared to industry best practice of between 50% and 80% (Abam et al, 2011).The low capacity factor (5.23%) in October 2014 signifies that the average energy generation is low which implies under-utilization of plant capacity for a major part of this period of study. Effective planned maintenance and adequate gas supply will boost the plant capacity factor.

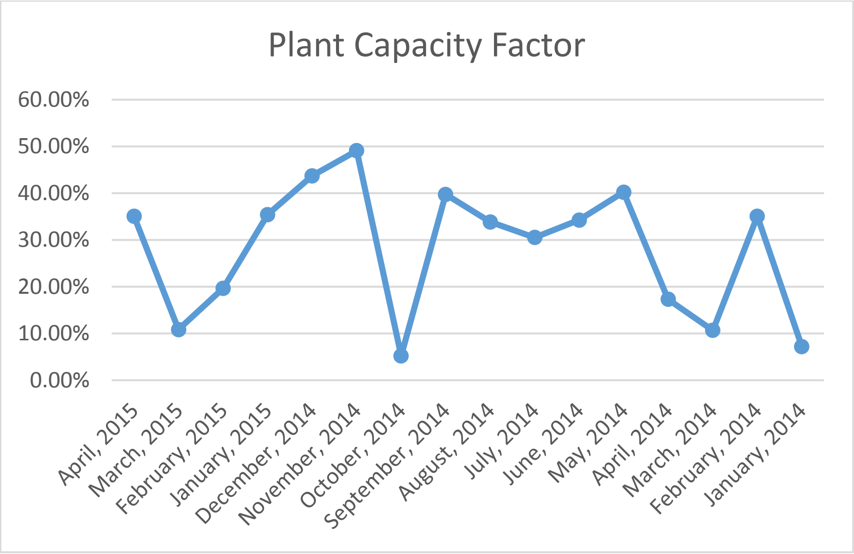


Figure 2: Monthly variation of capacity factor

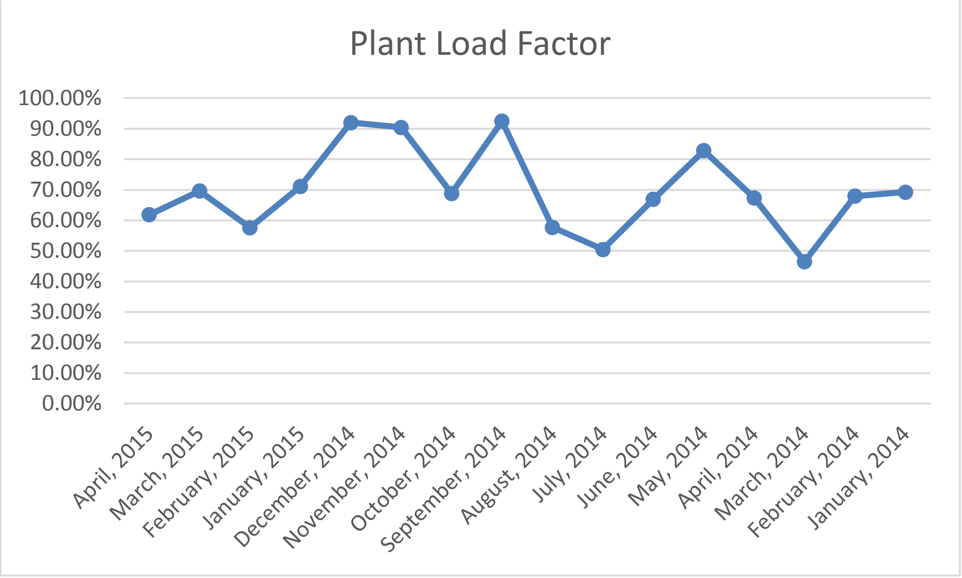


Figure 3: Monthly variation of plant load factor

The variation of station load factor on a monthly basis for the period under review is as shown in Figure 3. The load factor varies from 46.50% to 92.46% with an average value of

69.54%. This is low when compared to international best practice of 80% (Melodi and Franklin, 2011). The load factor is indication of the utilization of the power plant capacity. A high load factor means that the total plant capacity is utilized for most of the time and is desirable from the point of view of reducing cost of generation per unit of energy (N/MWH). Effective politics and management will be required to ensure adequate, reliable and cost effective operation of the electric power generation plant.

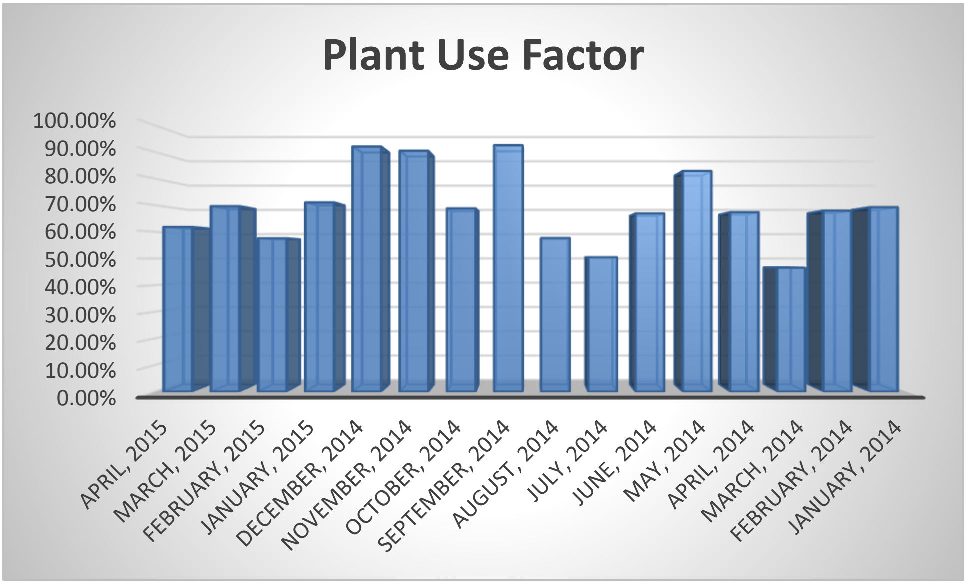


**Figure 4: Variation of plant use factor**

Figure 4 shows the plant use factor. The average plant use factor for the period under review is 69.54% with a minimum of 46.50% in March, 2014 and maximum value of 92.46% in September, 2014. This is low as compared to average plant use factor of 92.01% in AES Barge Gas Turbine Plant(Oyedepo et al,2014). High plant use factor indicates high ratio of actual generation to expected generation, while low plant use factor is an indication of low ratio of actual generation to expected generation. Low use factor also indicates under-utilization of the plant thus plant's generation below rated capacity. The utilization factor was the same as the plant use factor as shown in Figure 4. The utilization factor for the plant is not too far from best practice (over 95%) (Oyedepo et al, 2014;Obodeh and Isaac, 2011;Ikpambese etal, 2014).

Low generation unit cost and fuel unit cost are desired for economic efficient power generation in a power station. Figure 5 shows how they vary. The plant operated at its economic best in February 2014 with the lowest generation unit cost in that month. The generation unit cost was highest in October 2014**.**

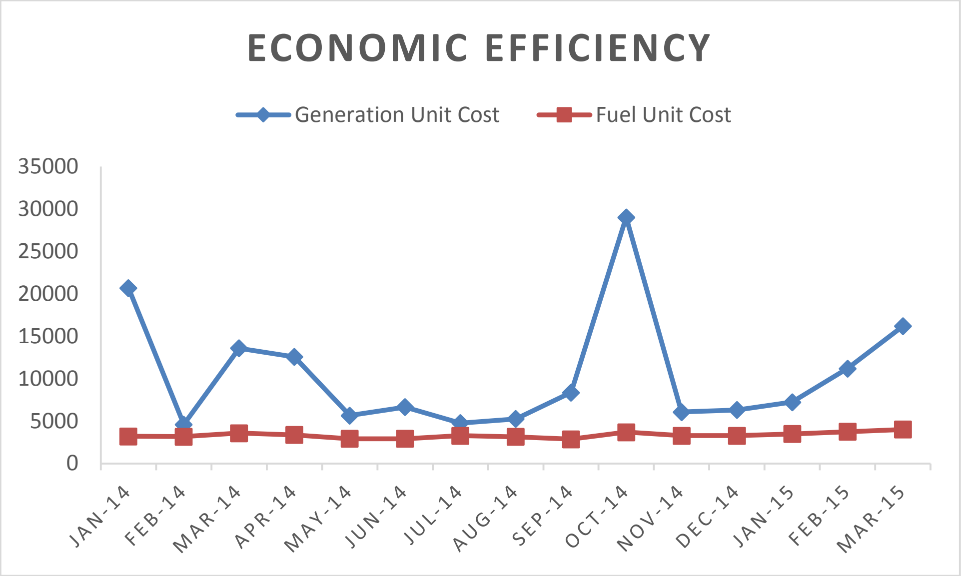


Figure 5: Economic Efficiency of the plant

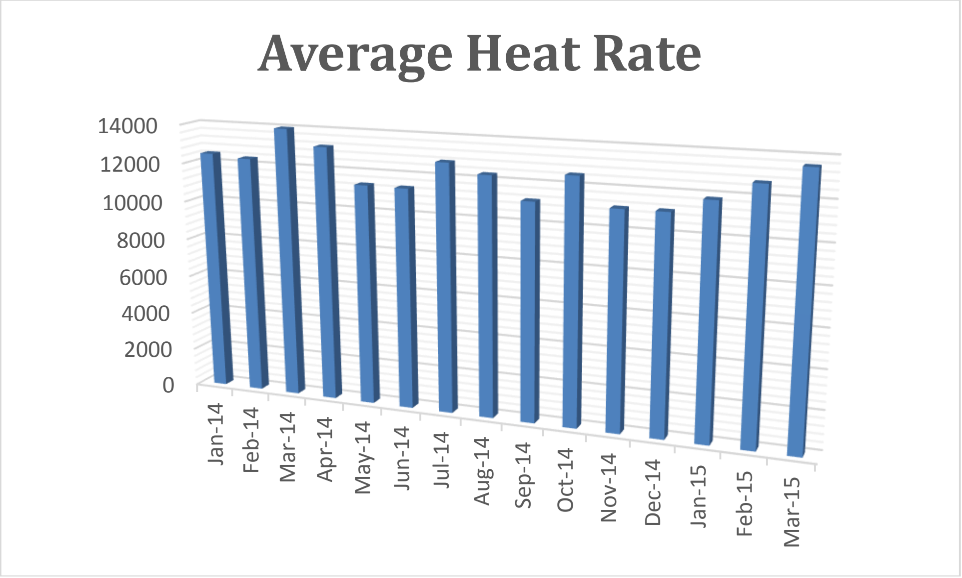


**Figure 6: Monthly variation of Heat Rate**

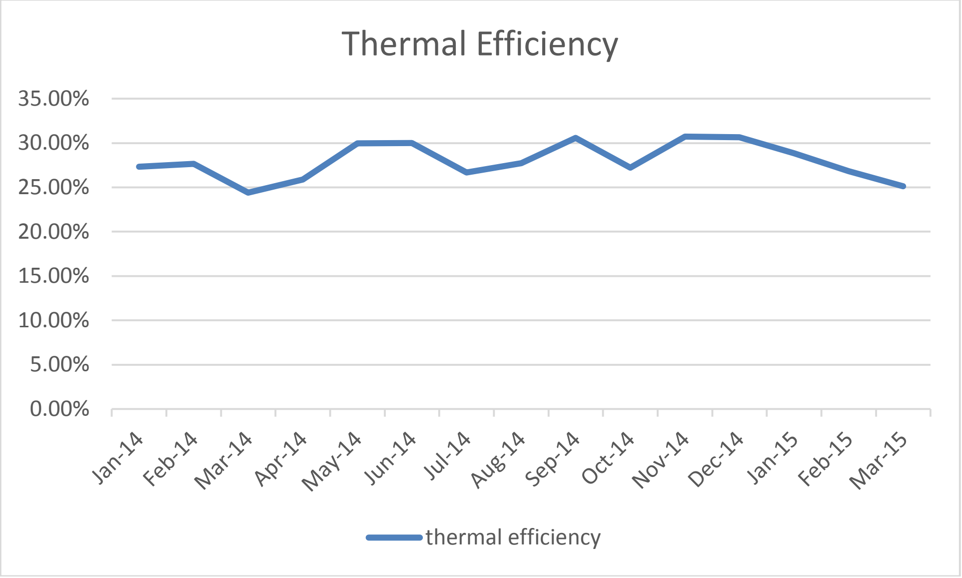


Figure 7: Thermal Efficiency for the period

Figure 6 shows the heat rate of the plant. The heat rate can be improved by addition of a steam plant (cogeneration). The thermal efficiency also is shown by Figure 7. This ranged from 24.40% to 30.71% with an average of 27.98. This compares favorably with the designed cycle thermal efficiency of32.4% and 48.2% under cold-air-standard assumptions. The linear model was fitted based on the natural values of the power generated, breakdown maintenance index and cost, planned maintenance index and cost, fuel cost and the gas volume utilized without the transformation of neither the response (power generated) nor the predictors. The empirical first order linear regression model generated after inputting these values into Minitab 17 generated undesirable results revealing that there are some terms of the true responses that were not sufficiently estimated in the linear regression model. Thus improvement was made on the model to enable adequate estimation of the response. This was done by investigating the impact of interactions on the response.

Equation 9 shows the improved monthly power model involving interactions of the predictors and terms in the model still using Minitab 17.

$$\text{Power} = -4771 + 6042\ \text{BMI} + 0.000119\ \text{BMC} + 0.000134\ \text{Fuel\_Cost} + 55.1\ \text{GVU} - 0.000226\ \text{BMI BMC} \quad (9)$$

Where:

BMI = breakdown maintenance index

BMC = breakdown maintenance cost (N)

Fuel_Cost = cost of fuel for the month (N)

GVU = gas volume utilized (MMSCF)

The breakdown maintenance index is a ratio of number of breakdown defects rectified to the number of breakdown maintenance defects reported. Mathematically,

$$\text{BMI} = \frac{\text{no of breakdown defects rectified}}{\text{no of breakdown defects reported}} \quad (10)$$

The analysis of this improved model for appropriateness indicates that the improved model is significant and fit. The indicated values of $R^2$ and adjusted $R^2$ as 99.56% and 99.41% respectively are desirable.

Table 1: Table of residuals

| Actual Generation | Predicted Generation | Residual | Error |
|---|---|---|---|
| 44812.7 | 44923.3 | -0.002469 | -0.00001% |
| 15116.9 | 15044.5 | 0.004793 | 0.00003% |
| 23693.9 | 24624.8 | -0.039289 | -0.00017% |
| 56896.0 | 54859.0 | 0.035803 | 0.00006% |
| 46912.0 | 45819.7 | 0.023284 | 0.00005% |
| 43196.6 | 46771.4 | -0.082757 | -0.00019% |
| 47853.4 | 47303.4 | 0.011492 | 0.00002% |
| 54358.2 | 53231.1 | 0.020734 | 0.00004% |
| 7394.9 | 7158.5 | 0.031976 | 0.00043% |
| 67169.1 | 65888.9 | 0.019058 | 0.00003% |
| 61834.8 | 60678.1 | 0.018707 | 0.00003% |

The adjusted $R^2$ is particularly useful for comparing models with different number of terms especially when model reduction takes place and the adjusted $R^2$ for the improved model is higher than the first linear model fitted with respect to the monthly power response. Table 1 shows the residuals and the predicted monthly power generated. From the information presented, it can be seen that the predicted generation is close to the actual.

**4.0. Conclusion**

This study investigates the performance of Ibom Power Station using key performance indicators (plant use factor, plant utilization factor, plant capacity factor, and plant load factor), heat rate and generation unit cost. The plant capacity factor ranged from 5.23% in October 2014 to 49.10% in November 2014. The average plant use factor for the period reviewed was 69.54% (46.50% minimum and 92.46% maximum) as against set standards of 50% and 70% respectively. The maximum and minimum plant load factor for the period under review stood at 92.46% in September 2014 and 46.50% in March 2014. The average load factor of the station was 69.54% which was quite lower than best practice of 80%. The low plant capacity was due to inadequate gas supply. The thermal efficiency, generation cost and heat rate of the plant was found for the period under review. It is obvious from the results obtained in this research that the plant operates well below capacity throughout this period. A regression analysis was performed to predict future power generation at the power station. This should enable the National Control Centre, Oshogbo to effectively share power to be sent to the national grid by the power station.

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