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A STUDY AND PERFORMANCE EVALUATION OF OLORUNSOGO THERMAL POWER PLANT IN NIGERIA

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ABSTRACT

Nigeria with a population of well over 170 million people derives her bulk electricity supply from both Hydro and Thermal power plants. The plants, located in different parts of the country should be such that power should be generated and delivered to consumers efficiently and appropriately. This calls for the need to evaluate the performance of these plants periodically to ensure that they are kept in top form. The Olorunsogo Thermal power plant with an installed capacity of 690MW was studied, analysed and evaluated using data covering 2013 to 2017.The results show that the maximum overall efficiency (32.01%) occurred in 2015 as against the expected value of 40 – 45%. The minimum overall efficiency (25.29%) was recorded in 2017. Similarly, the maximum and minimum overall thermal efficiencies were 32.66% and 25.81% and they occurred in 2015 and 2017 respectively. The reliability figures were 86.54% (maximum), attained in 2015 and 83.79% (minimum) scored in 2016. The international best practice recommends 60% and above for overall efficiency and 75% and above for thermal efficiency and 98% and above for reliability respectively. Comparatively, the calculated values of performance indices fell short of the international standard. Besides, the average overall efficiency in the years under study was 29.0%, the thermal equivalent was 29.6% and the reliability index was 85.6%. These calculated indices definitely vary from the standard, implying that the plant performance has to be improved upon. How this could be done has been suggested

KEYWORDS: Efficiency, thermal plant, reliability, installed capacity.

I. INTRODUCTION

Nigeria has as many as 25 power plants including the independent power plants (IPPs).Out of this number, 22 constitute the thermal power plants. About 84% of the country's power demand is supplied by thermal plants (NCC, 2015). These plants depend on natural gas for their operation, just as the hydro power plants rely on huge availability of water. Consequently, the plants' operations are affected by instability in gas supply occasioned by, besides, vandalism and criminal activities of some restive youth.

In 2016, Olorunsogo power plant/station generated only 164,454.10MWH of energy, down from the 918,691.97MWH it generated in 2013. This contributed to the worsening energy situation in Nigeria. As a result, a large number of consumers have resorted to self-generation of power in order to ensure an adequate and stable power supply. Consequently, it was reported (The Punch, 2014) that 796.4 billion naira (about 2.2 billion U.S. dollars at an exchange rate of 365 naira to a dollar) was spent on fuelling generators with concomitant negative effect on the environment. To buttress this ugly situation, the World Bank estimates that about 85% of businesses in Nigeria own electricity generators and that privately-owned self-generating power accounts for approximately 40% of the total capacity in Nigeria (Lathan & Watkins, 2011).

In comparison, Kuwait and Qatar offer free electricity to their citizens while Kingdom of Saudi Arabia, Bahrain and Oman subsidise electricity prices for their citizens (Qader, 2009).These are countries with huge oil and gas deposit, just like Nigeria.Similarly in South Africa, a free Basic Electricity Policy (FBE) was introduced in 2001 by Eskom, following the suggestions made by the Department of Minerals and Energy. According to Inglesi (2013), this privilege was given to all consumers irrespective of their income levels.

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Thermal power plants such as Olorunsogo could be made to function much more efficiently if their operations are periodically evaluated or assessed. Such an assessment would generate useful data to serve as input for enhancing its future performance.

II. LITERATURE REVIEW

The Olorunsogo power station (plant) in South-West Nigeria commenced operation in March, 2011 but was officially commissioned by the then President of the Federal Republic of Nigeria on February 20, 2015. It is a combined cycle power plant consisting of four gas turbines (GTs), four heat recovery system generators (HRSGs) and two steam turbines (STs). What this implies is that the exhaust gas which is supposed to be a waste heat is channelled through the heat recovery steam generator (HRSG) to produce steam for the steam turbine, thus increasing the overall available power generation.

Generally, in Nigeria, about 84% of grid electricity comes from thermal power station while 16% is contributed by the hydro plants (NCC, 2015; FRN, 2012). According to Okoye, (2017), as at December 2015, the total installed capacity of all power plants connected for grid operation was 12,132.40MW while the average available capacity throughout 2015 was 6401.20MW. This corresponds to plant availability factor (PAF) of 0.53 or 53%. Out of the national average available grid capacity of 6401.20MW, in 2015, Olorunsogo plant presented 673.25MW or 10.5% of the total (NCC, 2015).

Similarly in 2015, the total installed capacity of all thermal power plants including the independent power plants (IPP) was 10,194.4MW while that of hydro power plants was 1,938.4MW or 16% of the nation's total installed capacity.In Nigeria, electricity is not generated from coal in spite of its abundant supply. (Olayande&Rogo, 2008; Okoye& Ali, 2010). Natural gas, the main fuel required for electricity generation is supplied by the Nigerian Gas Company.Statistics from NCC (2015) show that the quantity of gas consumed by all the 11 thermal power plants (including the IPPs) in 2015 was 258051933469.21 Standard Cubic Feet (SCF). Out of this, Olorunsogo plant consumed 45398827688.71 SCF or 17.6% of the annual total.

As a result of high dependence of Nigeria on thermal power plants for her electricity needs, an increasing interest is being developed in the study, evaluation, assessment or analysis of her existing thermal plants.The idea is to ensure that the very significant thermal power plants which constitute the major installed capacity of a country such as Nigeria are efficiently managed and utilised.

III. METHODOLOGY

Visits were made to Olorunsogo station, Ogun State, South-West of Nigeria. Empirical data spanning January 2013 to May 2017 as prepared by the performance management department of the power station were collated. Such data includes:

- Installed capacity of the power plant (MW)
- Gross energy generated (MWH)
- Quantity of fuel gas consumed (Standard Cubic Feet, SCF).
- Net caloric value of fuel gas (KJ/m^3)
- The expected operating time of the various generating units at the power station.
- The down-time suffered by the various generating units at the power station.

Though the Olorunsogo power station started operation in ***March 2011,*** the station authority could supply data in the areas requested for only 2013, 2014, 2015, 2016 and partly 2017 (up to May, 2017). The data were then used to calculate:

- The overall efficiency of the power plant for each of the year under study.
- The thermal efficiency of the plant for each of the year under study.
- The reliability of the power plant for each year.

The mathematical models for determination of the plant performance parameters were considered.

Thermal Efficiency

Gupta (2004) defines thermal of a steam power plant as the ratio of the heat equivalent of mechanical energy transmitted to the turbine shaft to the heat of combustion. It is generally as low as 30%.

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Mathematically, thermal efficiency is given as
=

Overall Efficiency

This is defined (Adegboyega&Odeyemi, 2011) as

Where volume of gas in m^3
And SCF is standard cubic feet.
Net CV is the net caloric value of the gas as supplied by the Nigeria Gas Company (NGC). Its value is usually between 34000 – 36000 KJ/m^3

Reliability

For this study, reliability can be defined as the probability of a dangerous condition not occurring (Cooper, 1989).According to Nag (2001), a power plant should be able to supply electrical power at a minimum cost to the consumer.
The suitable model to use in calculating the reliability (R) of the Olorunsogo plant is:

IV. RESULTS AND DISCUSSION

Table 1.0. Shows the raw data as collected from theOlorunsogo thermal power plant:

Table 1.0. Olorunsogo thermal power plant: energy and efficiency profile.

Year	Installed capacity (MW)	Energy generated (MW) & MWH	Fuel gas consumed (SCF)	Net calorific value of gas (KJ/m^3)	Expected running time (Hours)	Down time (Hours)
2013	690	(104.87) 918691.97	11092187076	34508.00	52560	7428.56
2014	690	(100.46) 879990.19	11166232994	34795.56	52560	7484.65
2015	690	(132.67) 1162150.98	13254651488	34827.46	52560	7075.72
2016	690	(18.77) 164454.1	2113300439	34871.28	52560	8521.66
2017	690	(6.61) 57912.02	837688314.8	34748.56	21600	3046.5

Figure in bracket is equivalent power generation in MW as computed by the author using the expression:

Source: Olorunsogo thermal power station.

The data were then used to calculate the thermal and overall efficiencies for each year as follows:
For year 2013, the overall efficiency using equation (2) is:
Overall efficiency
=
= 0.3051 x 100%
∴Overall efficiency = 30.51%

Thermal efficiency, using equation (1) is worked out as follows:
Thermal efficiency
∴thermal efficiency = 31.13%
Similarly, for year 2014,
Overall efficiency
=
= 0.2879 x 100%
∴Overall efficiency = 28.79%
And thermal efficiency
= 31.13%

For Year 2015,
Overall efficiency
=
= 0.3201 x 100%
∴Overall efficiency = 32.01%

And Thermal efficiency
= 32.66%

For Year 2016,
Overall efficiency
=
= 0.2837 x 100%
∴Overall efficiency = 28.37%

And thermal efficiency
= 28.95%

For Year 2017 (January to May)
Overall efficiency
=
= 0.2529 x 100%
∴Overall efficiency = 25.29%

And thermal efficiency
= 25.81%

Furthermore, the reliability status was calculated for each year by using equation (3).

Thus, for Year 2013
Reliability, R = x 100%
= x 100%
= 0.8587 x 100%
∴ = 85.87%

Similarly, for Year 2014,
Reliability, R = x 100%
= x 100%
= 0.8576 x 100%
∴ = 85.76%

For Year 2015,
R = x 100%
= x 100%
= 0.8684 x 100%
∴ = 86.54%

Also for Year 2016,
R = x 100%
= x 100%
= 0.8379 x 100%
∴ = 83.79%

And for Year 2017 (January to May)
R = x 100%

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= x 100%
= 0.8590 x 100%
∴ = 85.90%

The calculated values of the reliability, thermal and overall efficiencies are summarised in Table 2.0.

Table 2.0. Olorunsogo power plant: Energy, efficiency and reliability profile.

Year	Installed capacity (MW)	Energy generated (MW) & MWH	Fuel gas consumed (SCF)	Net calorific value of gas (KJ/m^3)	Expected running time (Hours)	Down time (Hours)	Overall efficiency %	Thermal efficiency %	Reliability %
2013	690	(104.87) 918691.97	11092187076	34508.00	52560	7428.56	30.51	31.13	85.87
2014	690	(100.46) 879990.19	11166232994	34795.56	52560	7484.65	28.79	29.38	85.76
2015	690	(132.67) 1162150.98	13254651488	34827.46	52560	7075.72	32.01	32.66	86.54
2016	690	(18.77) 164454.1	2113300439	34871.28	52560	8521.66	28.37	28.95	83.79
2017	690	(6.61) 57912.02	837688314.8	34748.56	21600	3046.5	25.29	25.81	85.90
Total (Average)							29.0	29.6	85.6

From Table 2.0, the following graphs were plotted.

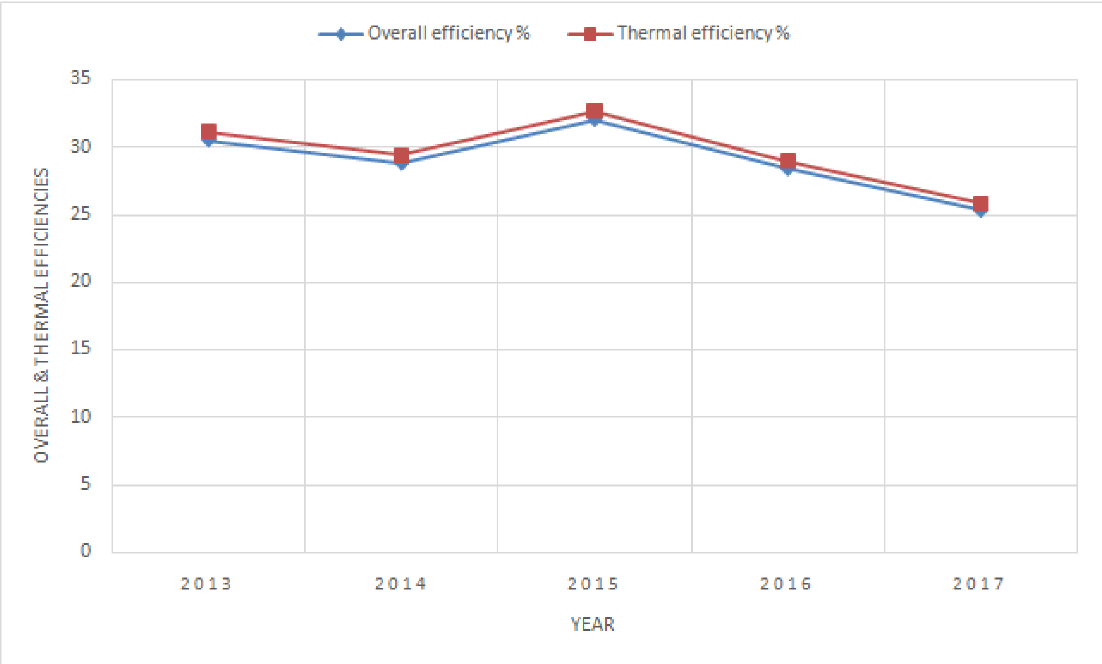

Fig 1.0. Variation of thermal and overall efficiencies with year

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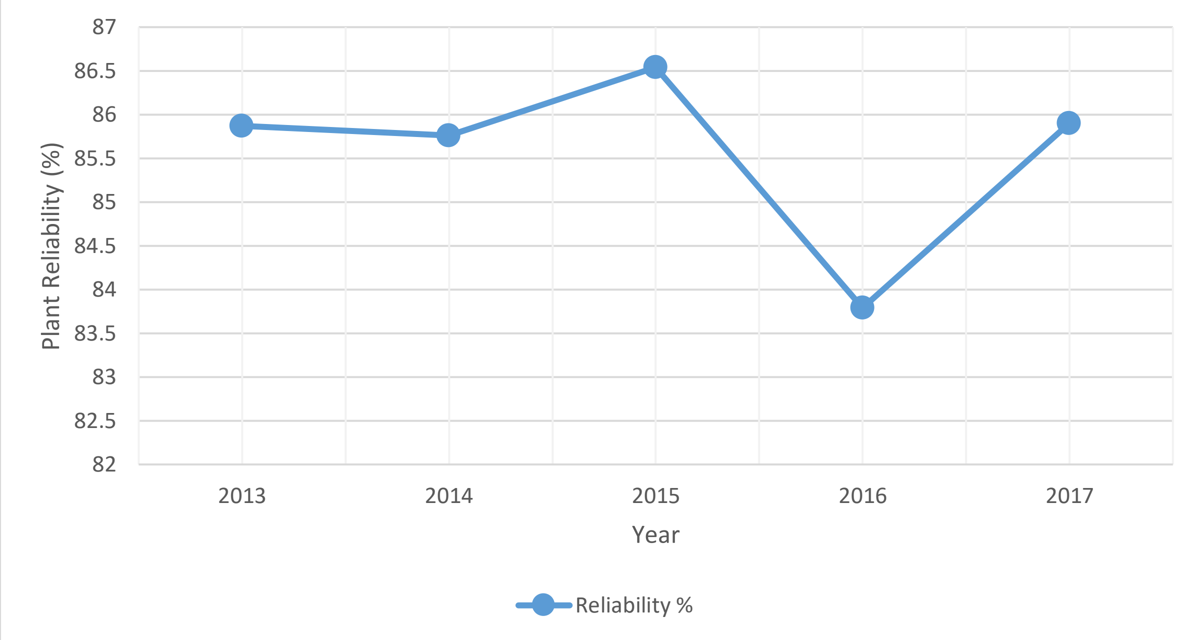

Fig 2.0. Variation of plant reliability with year

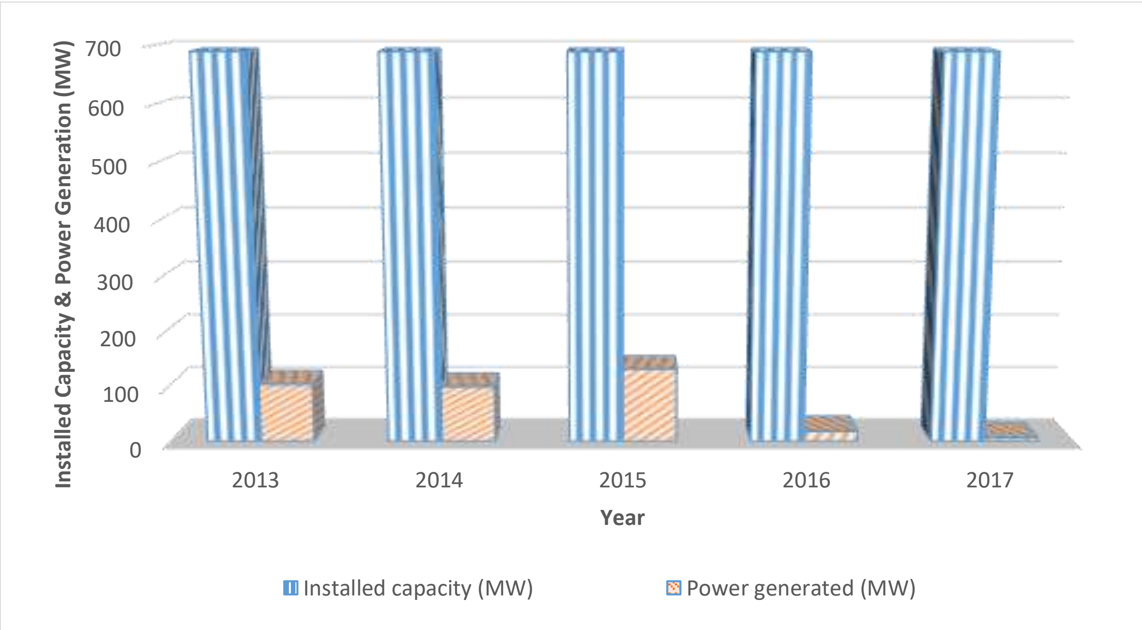

Fig 3.0. Yearly power generation of Olorunsogo power plant in relation to installed capacity

From Table 2.0, the average overall efficiency, thermal efficiency and reliability (2013 - 2017) were 29.0%, 29.6%, and 85.6% respectively.

It could also be seen that there is a variation in both the thermal and overall efficiencies of the plant in the years under study. The maximum overall efficiency of 32.01% occurred in the year 2015 as against the expected value of 40 – 45%.This implies that only 32.01% of the energy in fuel gas was converted to electrical energy and 67.99% was lost mainly as heat. This agrees with Nag (2001) that the rate of heat loss is inversely proportional to efficiency. In other words, the higher the heat loss, the lesser the efficiency. The minimum overall efficiency of 25.29% was recorded in 2017. The fact that the data did not cover the entire months of 2017 might not have a serious effect on the results of the study as data up to May, 2017 as supplied by the management of the station were used.

Similarly, the maximum overall thermal efficiency was 32.66%, occurring in 2015 while the minimum was 25.81% and it happened in 2017.

The maximum reliability was 86.54% and was achieved in 2015, the minimum was 83.79% as recorded in 2016. The international best practice standards (Adegboyega&Odeyemi, 2011) are 60% and above for overall efficiency, 75% and above for thermal efficiency and 98% and above for reliability respectively. It could be seen that the calculated values (performance indices) are in most cases, clearly less than the relevant standard (reference) values, indicating that the performance capability of the power plant so far is not quite satisfactory. This may be adduced to ageing of components / parts of generating units, maintenance – related issues, obsolete technology and inadequate gas supply (among others).

This has also led to low electricity generation, the generating units should have higher running time and should not breakdown so often.

V. CONCLUSION

Olorunsogo power plant is one of the 22 thermal power plants operating in Nigeria. In 2016, it generated only 164,454.10MWH of energy in contrast to the high 918,691.97MWH generated in 2013. A study of the plant has been made and its performance evaluated using appropriate mathematical models. The values of reliabilities, thermal and overall efficiencies obtained over five-year study show that the plants performance has not been quite satisfactory. For instance, the average overall efficiency, thermal and reliability in the five-year span were 29.0%, 29.6% and 85.6% respectively. Compare these with the international best practices of 60% and above for overall efficiency, 75% and above for thermal efficiency and 98% and above for reliability.

VI. RECOMMENDATIONS

From the results of the study, the following recommendations are made:

- The pipeline should be periodically inspected and routine maintenance intensified to avert sudden disruption of gas supply to the plant.
- The automated systems/components of the plant should be run in that mode as much as possible. Manual operation should not be encouraged.
- The source of gas to the plant is too far, leading to occasional low gas pressure. Thus, a booster gas station should be devised through the cooperation of both the Nigeria Gas Company and the operator/owner of the power plant.
- The menacing Niger Delta crisis should be resolved permanently so that restive youths should not relish in blowing up gas pipelines at will.
- Training and re-training of technical staff should be emphasised in the face of fast technological changes all over the world.
- The authorities of the power station should do well to improve on their record-keeping as there is always room for improvement.

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