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Generation Cycle of Jebba Hydro Power Plant and its Effect on the National Power Grid

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Abstract: This paper presents the trend of power generation for the Jebba hydro-power plant and its effect on the Nigerian National Power Grid (NPG). Since electricity is used on a 24-hour basis, it is requiredto bestable and constantly available.However, it has been observed that there is usually a shortfall between the actual and available generated output power of hydro-power plants. Four years of power generation data (2003 – 2006) was analyzed to establish this trend.The data was acquired from hourly, daily, weekly and yearly inspection reading sheets of synchronous generators. The components of the data used include; the average available capacity (MW), the average actual generation (MW), the number of operational hours in a month, the total outage period (hours), the in-service period (hours), the reservoir computed inflow (m^3) and the total water discharge (m^3). It was observed that the power plant is only able to generate about 75% of its installed capacity for only two months (October and November) but less at the other months of the year. Positive correlations exist between the reservoir computed inflow (m^3), total water discharge (m^3) and the average actual generation. Tables and statistical charts were used to analyze the station's performance, and recommendations for improved performance was made. This study has established a trend of power generation which can be used for power generation planning for Nigeria to enable a constant supply of electricity.

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1.0 INTRODUCTION

Consumers of electricity in Nigeria have been looking forward to an improved and a more stable power supply from what is presently obtainable. For this reason, several efforts have been made over the years to improve the power supply available to the end users.

Electricity was first generated in Lagos in 1896 and the total capacity of the generators used then was 60 KW. In 1962, Niger Dams Authority (NDA) was established with the mandate of developing hydro power potentials. Later on, however, several other towns established isolated generators;these undertakings were later amalgamated into Electricity Corporationof Nigeria (ECN). In 1972, the ECN was merged with the NDA to form National Electric Power Authority (NEPA). This authority has the responsibility to generate, transmit, distribute, and sell electricity to consumers at a tariff rate approved by the Federal Government of Nigeria (Aduloju, 1999; NIPP transactions, 2015; NERA, 2015).

The prime consideration of an electricity generation station is the production of electrical energy. This energy must be transported to the load centers that have the requirement for such energyvia an electric power system (Aduloju, 1999; Donnely, 1985).

Since natural sources of energy are located neither in one area nor near major load centers, generation stations are,therefore, scattered around the grid built to poll the generated outputs from these sources. Electricity in Nigeria is generated from either thermal power stations which use mineral oil and gas fuel or hydro power stations employing the potentials of dammed rivers.

Hydropower generation stations are usually located at a site on a river where there is a sudden change in the river elevation. A dam is constructed to contain the hydraulic head (difference in elevation) and the mechanical energy of the water is transformed into electrical energy by allowing the water to fall through hydro power turbines (water wheels) which in turn drives the alternators. The turbines are directly coupled to the alternators by steel shafts. Thus, when the turbines are caused to rotate by the falling water, the alternators also rotate and in this way produce electric power (Aduloju, 1999).

Kainji, Jebba and Shiroro hydro power plants use the potential of river Niger to generate electricity as enumerated earlier. In this paper, the Jebba hydro power station is taken as a case study. Here, six synchronous generators are installed, each with a capacity of 96.4 MW which brings the total station capacity to 578.4 MW. The dam capacity of the station is given in table 1.

Table 1: Jebba hydro power station's dam capacity

Normal operating water level	103.0 m
Minimum operating water level	99.0 m
Live storage approximation	1000,000,000 m^3
Length of Kainji dam to Jebba dam	100 km

Sources: (Aduloju, 1999; JHEP, 2006).

With the rate of technological advancement currently taking place the world over, economies have become increasingly dependent on reliableand qualitative supply of electricity (Ali *et al.*, 2004; Theraja and Theraja, 2005; Megbowon and Oyebisi, 2005).Since electricity is vital to economic growth and development, it becomes expedient that it is readily available and of good quality (Popoola *et al.*, 2011). This research work has become necessaryfor planning purposes since the trend of power generation can be established.

2.0 Methodology

The work was carried out in two phases. The first phase is the acquisition of the research data from the Jebba hydro-power plant in Jebba, Niger state, Nigeria. The data was acquired from hourly, daily, weekly and yearly inspection reading sheets of synchronous generators. The data spans four years (2003 to 2006). The components of the data includes; the average available capacity (MW), the average actual generation (MW), the number of operational hours in a month, the total outage period (hours), the in-service period (hours), the reservoir computed inflow (m^3) and the total water discharge (m^3). These components of the data are represented in numerical values to facilitate quick understanding of the relationship in the data at a glance. This can be seen in table 1, a sample data for some months in a typical year under review.

The second phase has to do with analyzing the research data using spreadsheet programs. At this stage, we used descriptive statistics such as bar charts, line graphs and averages or means.

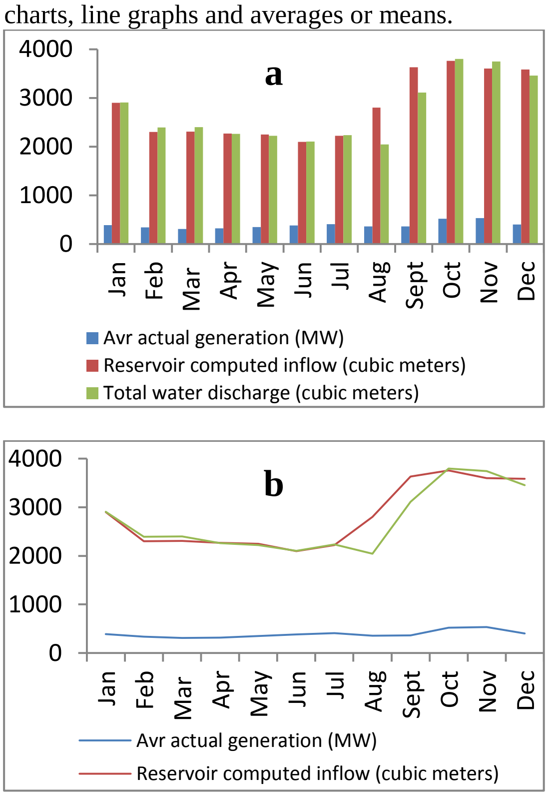


Fig. 1: Monthly generation statistics for year 2003 (a) bar chart (b) line graph

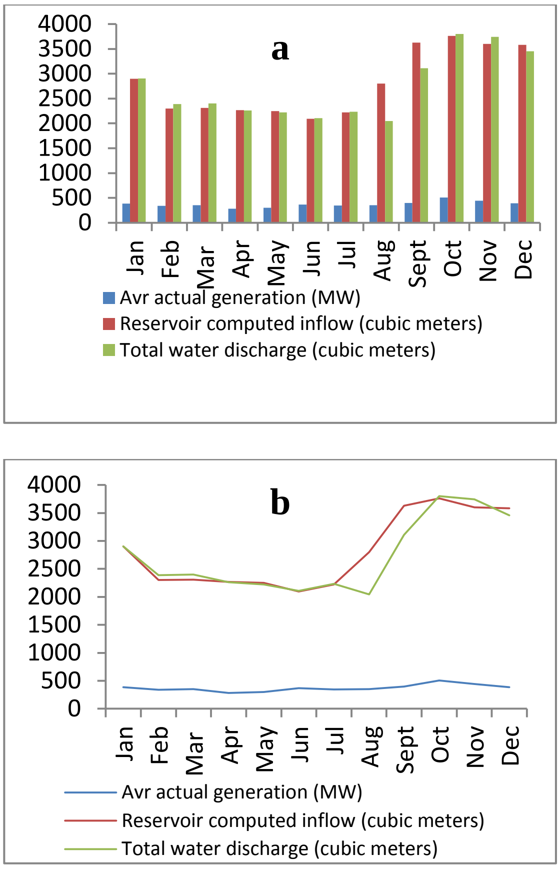


Fig. 2: Monthly generation statistics for year 2004 (a) bar chart (b) line graph

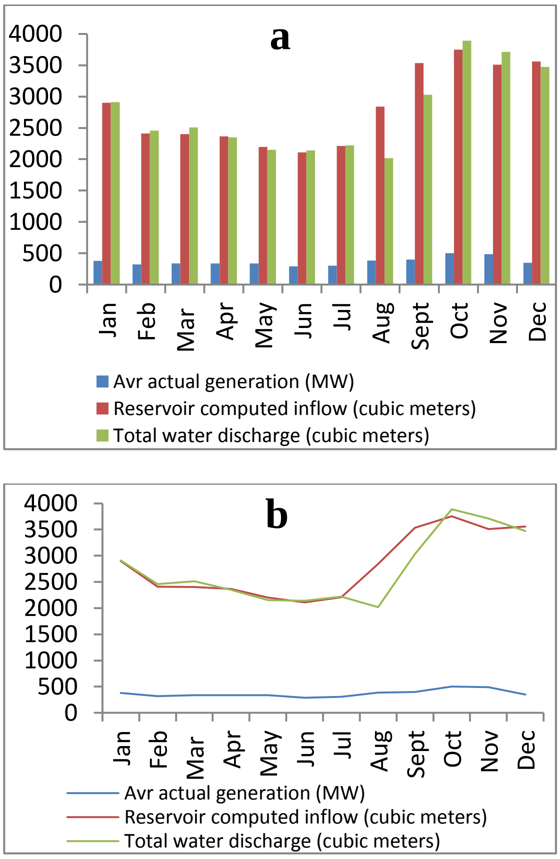


Fig. 3: Monthly generation statistics for year 2005 (a) bar chart (b) line graph

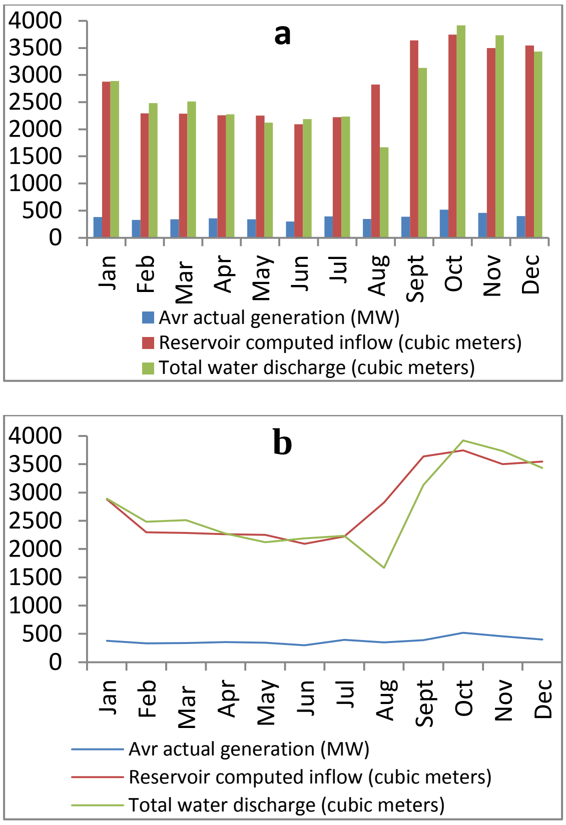


Fig. 4: Monthly generation statistics for year 2006 (a) bar chart (b) line graph

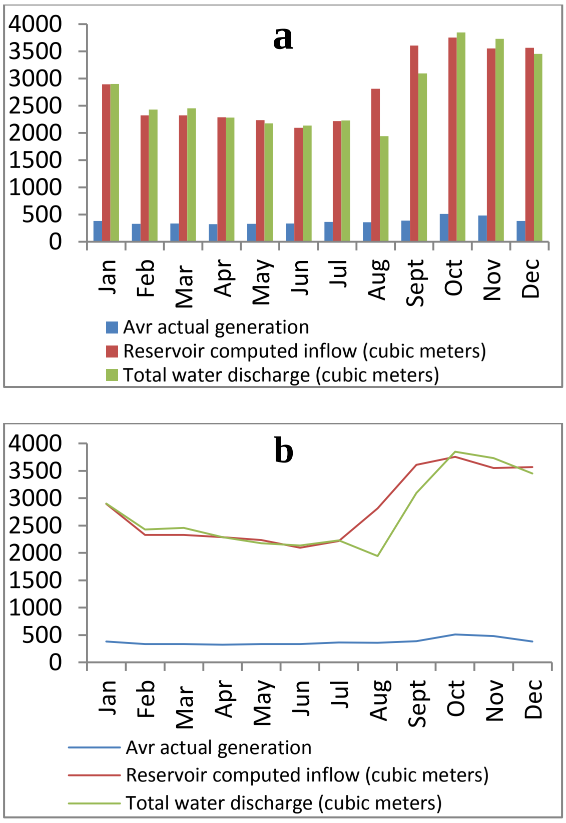


Fig. 5: Average monthly generation statistics 2003 – 2006 (a) bar chart (b) line graph

To establish a trend of power generation for the Jebba hydro-power plant, the individual years were reviewed separately based on the monthly generation level and the means of the monthly generation levels for the four years reviewed was determined. Also, the correlation coefficients of the quantities were studied.

3.0 RESULTS AND DISCUSSION

Figures 1 – 4 show bar charts (a) and line graphs (b) comparing the reservoir computed inflow (m^3) and total water out-flow (m^3) with the average actual generation (MW) for the four years under review. Figure 5 shows the average monthly generation statistics (a) as bar chart and (b) as line graph for years (2003 – 2006)

Power generation trend

The power generation cycle for Jebba hydro power plant for years 2003 – 2006 are presented in figures 1 – 4 showing the monthly: reservoir computed inflow (m^3), total water discharge (m^3), and the average actual generation (MW). For year 2003, the reservoir computed inflow ranges from 2095 in June to 3760 in October; total water discharge from 2045 in August to 3800 in October; and the average actual generation from 310.22 in March to 533.2 in November. This is also observed for the other years reviewed but with different valuesas could be seen from the plots.

It is observed that the highest level of power generation is usually experienced between October and November. This is as a result of the water volume build up in the reservoir which usually begins in July, peaks in October and declines from November until June of the preceding year. This implies that the station usually achieves peak actual generation between October and November of every year and this stands above 500 MW. Figure 5 clearly shows this trend of water volume flow for the station and the observation agrees with earlier reports that the months between June and September usually depict the peak of the rainy season almost throughout Nigeria (Odiba, 2014; Sunmonu et al., 2016).

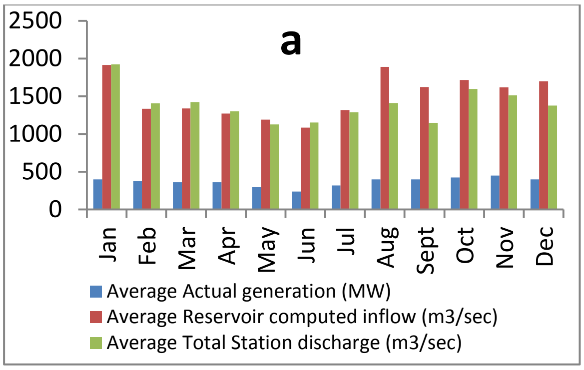
Using statistical analysis, the average actual power generation is strongly correlated to the average reservoir computed inflow and average total water discharge with correlation coefficients of 0.8228 and 0.8728 respectively. This trend agrees with the observation that power supply is seasonal with better power availability during the wet season than the dry season (Popoola *et al.*, 2011).

Table 1: Sample data for four months in year 2003

Year 2003	Average Available Capacity (MW)	Average Actual generation (MW)	No. of hours of the month	Total outage period (hours)	In service period (hours)	Reservoir computed inflow (m^3)	Total water discharge (m^3)
January	570	390.20	744	12	732	2900	2905
February	570	340.40	672	15	681	2300	2390
March	540	310.22	744	14	730	2310	2401
April	570	320.00	720	20	700	2265	2261

Result validation

The data used in this research spanned four years (2003 – 2006) and to validate the result, we have used two years of data (2010 – 2011) which shows a good correlation between the two sets of data. The data sets are about a decade apart and the trends obtained are similar (figure 6). The only deviation observed in the later data was in the months of May and June which showed a drop in the average actual generation and this is due to low number of units available for the months. From the result gotten from the two sets of data, all things being equal, the trend of power generation from the Kainji hydro-power station is as established.



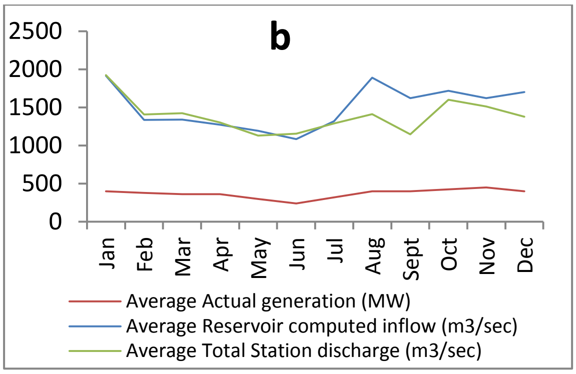


Fig. 6: Average monthly generation statistics for years (2010 – 2011) (a) bar chart (b) line graph

Effects on the national power grid

The Hydro-power generation stations in the country contribute approximately 19% to the overall installed power generation capacity and about 17% to the total available capacity (NIPP, 2015) which comes to about 1,938 MW installed and 1,060 MW available.

The Jebba hydro-power station contributes about 29.82% to the total installed capacity contribution from hydro-power. Hence, the available capacity varies from month to month depending on availability of the constituent units of the generation stations. From figure 5, it can be seen that the highest average generation from the power station stands at 511.8525 MW in the month of October which represents 26.41 % of total hydro-power contribution to the national grid; this represents a short fall of 3.41 %. The lowest average generation from the power station stands at 324.87 MW in the month of April representing a 16.76 % of the total hydro-power contribution; this also represents a 13.06 % shortfall. This gives the highest and lowest average contribution from the power station to the national power grid in the best and worst months of the year.

The average monthly percentage contributions are 19.86 %, 17.20 %, 17.31 %, 16.76 %, 17.18 %, 17.24 %, 18.75 %, 18.64 %, 19.99 %, 26.41 %, 21.62 % and 19.84 % for January to December respectively which gives shortfalls of 9.96 %, 12.62 %, 12.51 %, 13.06 %, 12.64 %, 12.58 %, 11.07 %, 11.18 %, 9.83 %, 3.41 %, 8.20 % and 9.98 % from January through December. These shortfalls are experienced as a result of the fluctuating water level which is strongly influenced by the rainfall pattern in the country.

The cycle of generation so established implies that for most part of the year, the station would not meet up with its expected contribution of 29.41 % to the NPG. The station's contribution is less at the white flood period and more at the black flood period of the year (KPS, 2015).

4.1 CONCLUSION

This study establishes the power generation trend for the Jebba hydro-power plant using four years of data and its effect on the National power grid (NPG). It has been established that the station generates more than 75 % of its installed capacity at the point where the reservoir inflow and outflow was at its peak which occurs in the month of October and November but less than this for the rest part of the year. The effect of this is that there is always a shortfall of the total power available to the NPG for most part of the year. Since a strong relationship exists between volume flow and power generation, then it makes valid the fact that power generation is seasonal in the country.

4.2 RECOMMENDATIONS

The overall result of the study shows that there is a trend to the contribution of hydro-power to the NPG and this should be carefully studied to allow for proper planning of power generation at any particular time of the year.

Proper data keeping should be encouraged to enable availability of the data for further research work as it becomes necessary.

This study should be extended to the other hydro-power plants in the country in other to have a holistic trend of hydro-power contribution to the NPG.

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