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Performance Analysis for Sapele Thermal Power Station: Case Study of Nigeria

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Abstract

Performance indices as measured by percentage of shortfall of energy generated, load factor, utilization factor and capacity factor of Sapele thermal power station in the period 1997 to 2006 is presented. The thermal station uses both steam and gas turbines. The station consists of six units of steam turbine and four units of gas turbine with total installed capacity of 1020 MW. But it was established that less than 17 % of the installed capacity was available. The percentage shortfall of energy generated for the period under review ranged from 27.4 to 49.1 %. This was due to aging of the plant equipment, improper operation and maintenance. The load factor was between 39.9 and 64 % as against International best practice of 80 %. The inability of Power Holding Company of Nigeria (PHCN) to do turn-around maintenance on the plant was advanced for the dismal value. Average plant availability of the plant for the studied period was less than 21% as against Industry best practice of over 95 %. The capacity factor was even more dismal. For the period under review, it ranged from as low as 5.49 % in 2006 to the highest value of 17.19 % in 1997. Low capacity factor indicates excessive plant failure. Measures to improve the performance indices of the plant have been suggested such as training of operation and maintenance (O & M) personnel regularly, improvement in O & M practices, proper spare parts inventory, organizing regular management meetings and improve general house keeping of the plant.

Keywords: sapele thermal plant, performance evaluation, reform

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INTRODUCTION

The long-term strategic intent of Nigeria is stated as to become "top 20 World economy in terms of size of gross domestic product (GNP) by the year 2020". Whilst this aspiration is long running, the goal post for its attainment has been shifted on a number of occasions (from 2000, to 2010, to 2015, to 2020) (Arikenbi, 2008; Sambo, 2007). However, without adequate and reliable electricity supply, socio-economic transformation would remain a mirage. In Nigeria, it has been a case of epileptic power supply. Nigeria produced 23.5 billion kWh in 2005 from about 6 GWe (giga watts electric) of plant and had final consumption of 17 billion GWh , giving per capita consumption of only 113 kW/yr (Ibitoye and Adenikinju, 2007; Nigerian Statistics Bureau, 2007). Current electric energy output is very low, with current installed capacity for energy generation put at 6,200MW, while actual output hovers between 2,500 MW and 3,200 MW (Nigerian Statistics Bureau, 2007). Nigeria's population size is 140 million, and to put the electric energy generation crisis in perspective, Sweden (population 9 million) generates 32,000 MW, South Africa (population 42 million) generates 36,000 MW and Lithuania (population 3 million) generates 3,000 MW (ECN, 2003; Ekeh, 2008; Ibitoye and Adenikinju, 2007). The government in power has for almost a decade advocated and emphasized the need to drastically improve energy generation output and efficiency of use. The government has backed up its desires by committing huge resources in this quest. However, the results achieved so far beg the issue (Iwayemi, 2008; Okoro and Chikuni, 2007).

In the Nigerian scenario, energy demand has not been addressed with the requisite planning that would guarantee concurrent capacity growth. Indeed, there has been a long persisting shortfall especially in electric energy output as compared with the demand in the economy (Oviemuno, 2006). Available data shows that the effective electric energy demand level at peak utility is in the region of 15,000 MW, whereas current energy output level averages at around 2,500 MW (World Bank world development indicator, 2006), (EIA-Energy Information Administration). The huge shortfall in energy supply is marginally redressed by rather inefficient and comparatively expensive private generation using diesel or gasoline powered back-up generating sets. It is estimated that an additional 30 % of effective total public utility electricity output (i.e. over 1,000 MW) of energy is generated using this inefficient means.

The additional cost to individuals and businesses arising from this extra expense for energy supply ranges from 200 % to 500 % over the retail cost of electricity (Odularu and Okonkwo, 2009; Okafor, 2008; Oviemuno, 2006). The spiral down effect on business and commodity cost in such an environment may be implied. On the flip side, large amounts of money are invested on improving energy generation on a yearly basis. It is estimated that as much as ten billion dollars ($10B) has been invested over the course of seven years, without any discernible positive implication on the availability of energy in the country, Nigeria (Ibitoye and Adenikinju, 2007). Indeed, in their paper on the subject, they projected that an annual investment of $10 billion per annum would be required over the next 20 years to achieve optimum power availability at optimum industrial and human capacity growth by the year 2030. There are about thirteen electricity generating installations servicing the national energy grid in Nigeria, with a combined energy outlay of about 6,801 MW (see Table 1)(although conflicting figures exist about the generating capacities of these power stations)(Arikenbi, 2008; Ekeh, 2008; Okoro and Chikuni, 2007; Sambo, 2007). However, the stations do not produce at maximum output on account of infrastructure failure, unsustainable management practices, and in some cases, economic sabotage (Akinbulire et al., 2007; Ikeme and Ebonhor, 2005).
Other reasons have also been suggested as being responsible for the problem but hardly has any of these reasons considered the issue from the point of how the plants are performing. One method NEPA/PHCN has used to beef up its actual power output from time to time has been the commissioning of new stations (Tables 2 and 3) (Ekeh, 2008; Sambo, 2007). Table 2 National integrated power projects (NIPP)

Table 1 Electric energy generating capacity in Nigeria as of the year 2006

Power station /Location	Type	Year of Commissioning	Installed capacity (MW)	Available capacity (MW)	Number of unit	Age of plant (years)	Remarks
Lagos station @Egbin	Thermal	1986, 1987	1,320	1,100	6	19-20	6 x 220 MW reheat steam turboelectric
Sapele station @ Ogorode	Thermal	1978,1981	1,020	790	10	25-28	6 x 120 MW steam and 4 x 75 MW gas
Delta station @Ughelli	Thermal	1966-1990	912	540	20	16-40	-
Afam	Thermal	1965-1982	711	488	18	24-41	-
Orji	Thermal	1956	30	-	4	50	-
Ijora station @ Lagos	Thermal	1978	60	40	3	28	3 x 20 MW (2 units working)
Lagos barge (AES)	Thermal	2000	270	170	-	6	-
Rivers IPP (Trans-Amadi station)	Thermal	2000-2002	30	-	-	4-6	-
Agip JV Okpai/Kwale, Delta	Thermal	2006	480	-	-	0	-
NESCO	Hydro/ Thermal	1929	30	-	-	77	-
Kainji	Hydro	1968, 1976, 1978	760	560	12	28-38	Some generators require major overhaul
Jebba	Hydro	1986	578	450	6	20	All units available
Shiroro	Hydro	1990	600	600	6	16	Some units repairs

Source: (Arikenbi, 2008; Ekeh, 2008; Okoro and Chikuni, 2007; Sambo, 2007)

Table 2: National integrated power project (NIPP)

S/No.	Station	Capacity (MW)
1.	Gbarain, Bayelsa	225
2.	Ihoubor, Edo	451
3.	Omoku, Rivers	230
4.	Sapele, Delta	451
5.	Egbeme, Imo	338
6.	Calabar, Cross Rivers	561
7.	Ikot Abasi, Akwa Ibom	300
8.	Ibom, Akwa Ibom	188
	Total	2,744

Source: (Sambo, 2007)

Table3 Independent power producers (IPP)

S/No	Station	Capacity (MW)
1.	Geregu, Kogi	414
2.	Omotosho, Ondo	335
3.	Papalanto, Ogun	335
4.	Alaoji, Abia	346
5.	Geometric, Aba	140
6.	Chevron JV, Agura, Igbin, Lagos	750
7.	Total Fina, Obite, Rivers	500
8.	Exxon Mobil, Bonny, Rivers	500
Total		3,320

Experience has shown that new power plants merely solve the problem in the short run. The technical problems that put out the older units no sooner than latter affect the new ones and they also go down. It would be necessary to find out why the plants perform below expectation. The objective of this study is to evaluate the performance of Sapele thermal power station over a period of ten years (1997 to 2006) and make recommendations on how to improve its performance.

MATERIALS AND METHOD

Data were obtained from Sapele thermal power station's logbook. These are inventory records of monthly energy generation between 1997 and 2006 and operational statistics showing the period when each of the plant units was first commissioned, period of major outage and the time of maintenance. In processing the data, percentage shortfall from target energy, load factor, capacity factor and utilization factor were obtained.The ratio of the number of units actually generated in a given period to the number of units which could have been generated with the same maximum demand is called the load factor (LF) of the station.

$$LF = \frac{L_{av}}{L_{mt}} \qquad (1)$$

where

L_{av} = average load generated

L_{mt} = maximum target load

The extent of use of the generating plant is measured by the capacity factor (CF), frequently termed plant factor or use factor. It is the ratio of the average energy output of the plant for a given period of time to the plant capacity.

$$CF = \frac{E_p}{C_{in} \text{ X } T_h} \qquad (2)$$

where

E_p = energy produced (kWh)in a given period

C_{in} = installed capacity of the plant

T_h = total number of hours in the given period

The utilization factor (UF) measures the use made of the total installed capacity of the plant.

$$UF = \frac{L_{max}}{C_{in}} \qquad (3)$$

where

L_{max} = maximum load generated in a given period

RESULTS AND DISCUSSION

The expected full load installed capacity of the plant is 1020 MW, but the generated energy for the period under review hover around 56 MW and 175 MW. It is glaring from Table 4 that the station targets are even a far cry from the installed capacity.

Table 4: Summary of Sapele thermal plant energy profile

Year	Energy generation (MWh)		Load figure (MWh)	
	Target	Actual	Energy consumed at the station	Energy sent out to the national grid
1997	2834880	1535744	155806	1382938
1998	2559300	1378392	79895	1303897
1999	2001600	1270980	94950	1176030
2000	1945268	1339625	87296	1252319
2001	2015760	1328755	100853	1227902
2002	1608240	1167021	73613	1093408
2003	1322884	904640	65164	839476
2004	1521840	1000589	71685	928905
2005	1450180	878415	61803	816612
2006	823456	490790	38610	452180

From the forth-going it means that less than 17 % of the installed capacity was available. This shows the large gap between installed and actual operational capacity of the plant which may be due to aging generating facilities that are poorly maintained.

Percentage shortfall from the target energy for the period under review is presented in Fig. 1. A reduction in shortfall indicates better performance of the plant. Fig. 1 shows a decrease in shortfall from 1998 to 2002, with all time low of 27.43 % in 2002. This may be due to the concerted efforts made in rehabilitation of the plant by the civilian administration in Nigeria on its advert in 1999. However, the gain could not be sustained due to inadequate supply of gas to the plant. The shortfall increases steadily from 2003 to 2006 with the highest value of 49.1 % in 2006. This is against the average acceptable value of between 5 and 10 % (Akinbulire et al., 2007, Kofoworola, 2003).

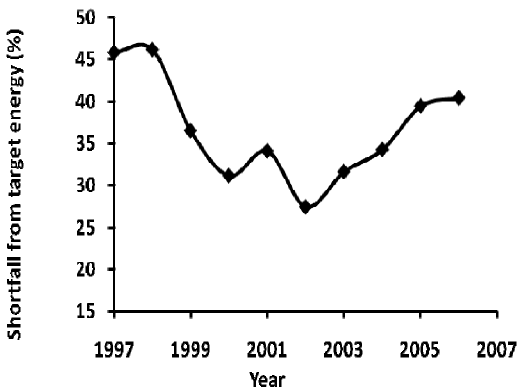

Fig. 1 Shortfall from target energy as a function Year

The following reasons have been adduced on why there has been inadequate gas supply. The recent history of Nigeria has been tainted with the uprising in the Niger-Delta where the gas for running the plant is obtained. The militants in the region had on several occasions disrupted the flow of gas (Okafor, 2008; Onohaebi, 2009; Akinbulire et al., 2007), hence jeopardizing energy generation. Thankfully, the Nigeria Federal Government has agreed a settlement with the Niger-Delta militants, the main suspects, in the damaging of the gas pipelines (Iwayemi, 2008). If not for anything, it would ensure that the militants are kept off the pipelines so that the plant will be fully operational. The other reason is the indebtedness of PHCN to the Nigeria Gas Company (NGC). To recover their money NGC on several occasions had to halt supply of gas to the organization to recover the debts (Igbinovia and Omodamwen, 2009). The former national electricity supply company, the National Electric Power Authority (NEPA) operated as a monopoly for years and had been responsible for the inefficiency in the power supply to the country. It is hope that the unbundling of the industry into six generation, one transmission and eleven distribution companies in 2007(Akinbulire et al., 2007; Igbinovia and Odiase, 2009) will help to cure its chronic inefficiencies. The variation of load factor with year is depicted in Fig. 2. As can be observed, there is a rise in load factor from 1998 to 2004, peaking at 64.04 % in 2004. This is a far cry from 80 % which is the value for international best practice (Akinbulire et al., 2007).

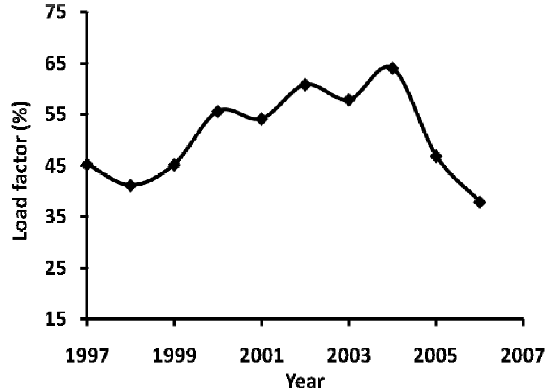

Fig. 2 Variation of load factor with year

The load factor is an indication of the utilization of 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 produced (Ekeh, 2001; Kofoworola, 2003). The reduction in cost with good load factor is due to the fact that overall working cost per unit becomes low, the fixed charges having been distributed over more units of energy generated. However, the load factor nosedives after 2004 reaching all time low of 37.9 % in 2006. This may be attributed to the inability of NEPA/PHCN to do turn-around maintenance on the plant as and when due. Effective management and strong political will is required to ensure adequate, reliable and cost-effective operation of the plant. Variation of utilization factor with year is shown in Fig. 3. The utilization factor had been on the decrease ranging from 21.99 % in 1997 to as low as 9.81 % in 2006 as against international best practice of over 95 % (Ekeh, 2001).

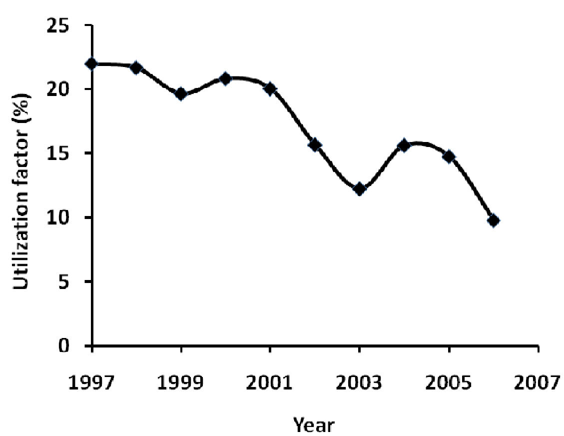

Fig. 3 Variation of utilization factor with year

This trend of utilization factor reflects how effectively managed the station is in terms of downtime. It was observed that there were some generating equipment that were utilized for less than their normal hours of utilization all year round. However, at different times some of them were inevitably idle for such reasons as undergoing routine inspection/maintenance and the development of fault. Planned and routine maintenance should be carried out to reduce the incident of downtime. However, additional gains can be achieved by replacement of essential spare parts.

The annual variation of capacity factor of the plant is as presented in Fig. 4. The capacity factor has been abysmally low between 1997 and 2006 with a maximum of 17.19 % in 1997 and a minimum of 5.49 % in 2006 as against industry best practice of between 50 and 80 % (Ekeh, 2001; Kofoworola, 2003). The characteristic behaviour of the plant depends substantially on the capacity factor and utilization factor (Akinbulire et al., 2007). It should be noted that a low capacity factor signifies that the average energy generation is low. This could indicate excessive plant failure. This means that most of its capacity remains unutilized for major part of the year, so the cost would be high. High value of capacity factor is desired for economic operation of the plant (Akinbulire et al., 2007). However, the actual power available at any time under reviewed period was less than 25 % of the total capacity due to poor maintenance. Inadequate maintenance even if it does not lead to frequent failure can at least increase overall operating cost.

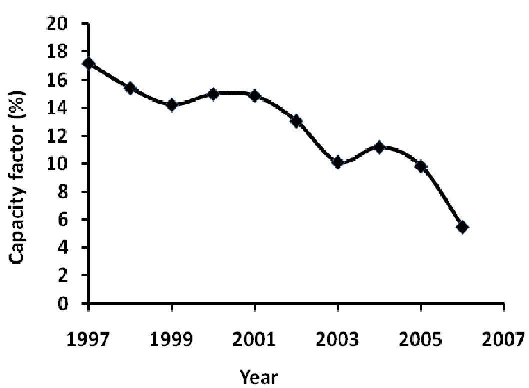

Fig. 4 Variation of capacity factor with year

Notably, routine maintenance was not carried out at scheduled intervals. The cumulative effect of the adhoc maintenance practices invariably reflects in the various units frequent failures. One can only conjecture that if the scheduled maintenance of the plant is significantly improved, high capacity factor will appear attainable given the exogenous sourcing of the needed spare parts. Spare parts procurement has been problematic, even critical spare parts order were sometimes shelved. Improved financial and economic health of the state-owned company NEPA/PHCN will enable it to provide and maintain acceptable minimum standards of service reliability, accessibility and availability.

CONCLUSION

The study revealed that less than 17 % of the plant installed capacity was available and that the percentage shortfall of energy generated between 1997 and 2006 ranged from 27.4% to 49.1 % as against the average acceptable value of between 5 to 10 %. Constant vandalism and attack on gas pipeline, PHCN indebtedness to NGC and age of the plant have been adduced for the above scenario. The load factor ranged from 37.91 to 64.04 % as against international best practice of 80 %. The inability of PHCN to do turn-around maintenance on the plant was advanced for the dismal values.

Average plant availability of the plant for the period under study was less than 22 % as against industry best practice of over 95 %. The capacity factor was even more dismal. The capacity factor for the studied period ranged from as low as 5.49 % in 2006 to the highest value of 17.19 in 1997. Low capacity signifies that the average energy generation is low. This could indicate excessive plant failure. Measures to improve the performance indices of the plant have been suggested such as training of O&M personnel regularly, improvement in O&M practices, proper spare parts inventory, organizing regular management meetings and improve general house keeping of the plant. Other measure is elimination or minimization of concerns about security of supply of gas associated with resource control agitation in Niger-Delta region. Credible and decisive effort to eliminate tension is more urgent than ever before.

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