Performance Evaluation of Egbin Thermal Power Station, Nigeria

I. Emovon, B. Kareem, and M.K. Adeyeri

***Abstract*-The main objective of this Paper was to evaluate the outage cost due to system downtime (Turbine failure) of Egbin Thermal power station from the year 1999 to 2008. The result of the analysis carried out revealed that for the whole ten years under review that there was a power generation loss of 46 percent of the Installed capacity putting the performance of the power station at 54 percent. Further investigation which is the aim of the paper revealed that the 46 percent of production loss resulted to revenue loss to the tune of $24,186,569,250. However a simple performance indicator was developed to evaluate the outage cost for the station which can also be applicable to other power station in Nigeria and beyond.**

***Index Term*- generation reduction, outage cost, generated capacity, installed capacity,**

I. INTRODUCTION

The history of electricity generation can be dated to 1896, when the public works Department (PWD) had 2 number of 30 KW generating plants powered by 2 number Davey- paxman locomotive type boilers double acting engines. The 60KW power generated by these 2 number of 30KW generators at 1000V was distributed along Marina, Lagos by using ten overhead circuits of 11swg solid copper wires carried on porcelain insulators supported by iron poles. Interestingly the frequency of the generators as at that time was 80 cycles per second against what we have today as 50 cycles per second, Manafa [1] as cited by Usifo et al. [2]

With the growth in industrialization and population, there has been an increasing demand for electrical energy in Nigeria. Power generation in Nigeria is mainly from three hydro-electric power stations, steam and gas thermal stations. Most of these facilities are being managed by PHCN, a government owned utility company that coordinates all activities of the power sector be it production, transmission, distribution, or marketing and sales [3]. Since inception of PHCN, the authority expands annually in order to meet the ever-increasing demand. Unfortunately, the majority of Nigerians have no access to electricity and the supply to those provided is not regular [4].

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I. Emovon is with the Federal University of Petroleum Resources, P.M.B.1221, Effurun, Nigeria (phone: +2348037092646, email: ikuoy2k@yahoo.com)

B. Kareem is with The Federal University of Technology, P.M.B. 704, Akure, Nigeria (email: karbil2002@yahoo.com)

M.K. Adeyeri is with The Federal University of Technology, P.M.B. 704, Akure, Nigeria (email: sademike2003@yahoo.com)

As at December, 2009 the number of Power stations in Nigeria was over 16, with installed capacity of 8,876 only 3,653 available. Thus 41% of the installed capacities were available [5].

The Nigerian power sector just like the downstream sector of the oil Industry has suffered ingloriously from poor maintenance problem [6]. The power stations could not follow their maintenance and as such, most of the plant units in the Stations always pack up. The Country is wonderful in planning but implementation is zero. It is the government that approves fund for project because the Industry is not fully deregulated. When fund is needed to overhaul a power station the Managers run back to government and if they do not provide funds, the units will be abandon. Things do not work this way. That is the may reason we advocated for complete deregulation in our earlier paper titled power generation in Nigeria: Problem and solution [5]. One of the Power station that is worst hit is the Egbin Thermal Power Station and it is the focus of this paper.

However the main objective of this paper is to evaluate the outage cost due to system downtime(Turbine failure) of Egbin Thermal Power Station from the year 1999 to 2008.

EGBIN THERMAL POWER STATION

Historical Background

The Federal Government in 1982 under President Shehu Shagari made a land mark decision to site a Thermal power station near Lagos in order to solve the perennial problem of inadequate power supply in the nation. At that time, Lagos metropolis power demand had grown to about 40% of the total energy generated. Egbin is a steam power plant with 6 installed units each having a capacity of 220Mw totaling installed capacity of 1320 Mw . According to [3], they are dual fired (gas and heavy oil) with modern control, single reheat; six stages regenerative feed heating.

The first unit of the power station known as ST- 3 was completed and commissioned on 11th May 1985. The remaining five units were commissioned one after the other within intervals of 6 months. Therefore between May 1985 and November 1987, the entire six units were handed over for commercial operation in the order: 3, 2,1,4,5, & 6, by Marubeni/Hitachi of Japan. Since commissioning, the station has remained the single largest power station in the country – contributing between 30% - 40% of the grid required. It is also the biggest power station in West Africa sub-region [7] The station was commissioned on oil firing. However Gas firing started in October 1988.

The power station has been generating power far below installed capacity due to maintenance problems. These problems have affected the availability and reliability of the power plant. However the maintenance management functions include both reactive and preventive. The PM type in place is time based, which is not effectively carried out, not to talk of practicing the state of art predictive maintenance. The preventive maintenance procedure and intervals are not well defined. Poor plant history records make it difficult to retrieve plant history and reports of plant/equipment, especially for old plants. This has resulted to the power station generating power far below installed capacity. Hence the Power generation reduction was evaluated in order to determine the outage cost due to system downtime.

Major Plant Component

There are four major components of the steam power plant[7] namely:

Boiler:

The demineralized water is sent to the boiler drum before lighting off the boiler and is later introduced as make up water at the hot well to augment for losses. The boiler has 9 sets of natural gas fuel burners, the natural gas is supplied to Egbin by NGC – a subsidiary of NNPC. Two burners are lighted off to pressurize steam. The boiler has a capacity of generating steam at **705 t/h**. The Boiler is dual firing . It uses either natural gas or High/Low Pour Fuel Oil(HPFO/LPFO) .

Turbine:

The turbine is a Tandem Compound Double Flow Reheat condensing tube type with 19 stages of expansion. The high pressure stage is an impulse- velocity compound type, while the LP stage is the reaction type . As the steam flows through the turbine blades, perpendicular force is induced on the rotor blade causing the rotor to revolve at high speed.

The superheated steam at a pressure of 12500kpa and a temperature of 538 ^{O}C turns the turbine at a speed of 3000rpm .Turbine rating is 220Mw.

Condenser:

The exhaust steam at a pressure of 8.5kpa from the LP turbine is condensed to water at the condenser .The condenser is a heat exchanger which is kept under vacuum through the steam jet air ejector .Circulating water from the lagoon goes through the condenser tubes while exhaust steam falls on the surface of the tubes which condenses to water and is recycled to the Boiler drum as feed water.

Generator:

The generator is directly coupled to the rotor of the turbine so they both turn at 3000rpm. It generates a 3- phase AC power of 220 MW at full capacity. Its windings are excited with a DC 440v. The windings are cooled with hydrogen gas at a pressure of 210 kpa.The generator current is 8.87A, with output voltage of 16kv, before being stepped up to 330kv by the generator transformer for onward transmission to load centres.

The unit transformer steps down the voltage from 16kv to 6.6kv for Unit auxiliaries' use.

II. METHODOLOGY

An extensive literature survey was carried. This was achieved by browsing on the internet, subscribing for journals, conference papers and contacting experts for information on power generation and existing ways of evaluating performance.

One month visit to Egbin Thermal Power station was embarked upon. During the period all relevant Data were obtained from Plant records. Data obtained includes; installed power generation capacity, generated capacity in MW and MWh among others as shown in Tables I,II,III,IV,V,VI,VII,VIII,IX and X.

Finally a simple Performance indicator were developed to evaluate the outage cost for the Power Station.

Performance Indicator

$$P_T = \sum_{i=1}^{n} P_{Ai} \qquad (1)$$

Where

P_T = Total power outage cost due to system downtime for n number of years,

P_A = Annual power outage cost for M number of Turbine,

$$\text{But } P_A = P_R \text{ X } P_F \text{ X } C_U \qquad (2)$$

$$P_R = \sum_{J=1}^{M} P_r \qquad (3)$$

$$Pr = P_{IC} – P_{GC} \qquad (4)$$

Where

P_R = annual power reduction for M number of turbine

P_r = annual power generation reduction for individual turbine,

P_{IC} = annual installed capacity in MWh for individual turbine,

P_{GC} = annual generated capacity in MWh for individual turbine

$$P_F = \sum G_c / \sum I_C \qquad (5)$$

Where

P_F = annual power factor for M number of turbine,

G_C = generated capacity in MW for individual turbine,

I_C = Installed capacity in MW for individual turbine,

C_U = unit cost of power

For the purpose of the research, we assume unit cost of power to be US$ 0.70 KWh

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Table I: Year 1999 Power generation Parameters

Unit	Installed Capacity (MW)	Installed Capacity (MWH)	Generated Capacity (MW)	Generated Capacity (MWH)
ST-1	220	1,927,200	204.91	1,672,562
ST-2	220	1,927,200	206.11	1,685,478
ST-3	220	1,927,200	185.88	1,359,482
ST-4	220	1,927,200	0.00	0.00
ST-5	220	1,927,200	193	1,205,435
ST-6	220	1,927,200	0.00	0.00
Total	1,320	11,563,200	989.9	5,922957

Table II: Year 2000 Power Generation Parameters

Unit	Installed Capacity (MW)	Installed Capacity (MWH)	Generated Capacity (MW)	Generated Capacity (MWH)
ST-1	220	1,927,200	206.91	1,563,564
ST-2	220	1,927,200	188.04	1,356,900
ST-3	220	1,927,200	208.73	366,294
ST-4	220	1,927,200	0.00	0.00
ST-5	220	1,927,200	207	1,732,890
ST-6	220	1,927,200	0.00	0.00
Total	1,320	11,563,200	810.68	5,019,648

Table III: Year 2001 Power Generation Parameters

Unit	Installed Capacity (MW)	Installed Capacity (MWH)	Generated Capacity (MW)	Generated Capacity (MWH)
ST-1	220	1,927,200	200.63	1,652,222
ST-2	220	1,927,200	203.94	1,753,524
ST-3	220	1,927,200	200.30	1,712,268
ST-4	220	1,927,200	175.13	1,204,487
ST-5	220	1,927,200	206	1,651,589
ST-6	220	1,927,200	0.00	0.00
Total	1,320	11,563,200	986	7,974,090

Table IV: Year 2002 Power Generation Parameters

Unit	Installed Capacity (MW)	Installed Capacity (MWH)	Generated Capacity (MW)	Generated Capacity (MWH)
ST-1	220	1,927,200	167.06	1,324,090
ST-2	220	1,927,200	185.41	1,520,460
ST-3	220	1,927,200	173.68	1,370,025
ST-4	220	1,927,200	152.52	836,325
ST-5	220	1,927,200	168.00	1,381,533
ST-6	220	1,927,200	164	439,071
Total	1,320	11,563,200	1,010.67	6,871,504

Table V: Year 2003 Power Generation Parameters

Unit	Installed Capacity (MW)	Installed Capacity (MWH)	Generated Capacity (MW)	Generated Capacity (MWH)
ST-1	220	1,927,200	141.86	1,143,541
ST-2	220	1,927,200	146.38	1,159,000
ST-3	220	1,927,200	148.57	1,141,902
ST-4	220	1,927,200	138.53	1,135,279
ST-5	220	1,927,200	143	1,197,206
ST-6	220	1,927,200	134	1,112,900
Total	1,320	11,563,200	852.34	6,889,828

Table VI: Year 2004 Power Generation Parameters

Unit	Installed Capacity (MW)	Installed Capacity (MWH)	Generated Capacity (MW)	Generated Capacity (MWH)
ST-1	220	1,927,200	177.19	1,339,773
ST-2	220	1,927,200	168.57	1,310,468
ST-3	220	1,927,200	180.65	1,412,183
ST-4	220	1,927,200	185.04	1,538,443
ST-5	220	1,927,200	157	1,202,182
ST-6	220	1,927,200	151	1,265,311
Total	1,320	11,563,200	1,019.45	8,068,360

Table VII: Year 2005 Power Generation Parameters

Unit	Installed Capacity (MW)	Installed Capacity (MWH)	Generated Capacity (MW)	Generated Capacity (MWH)
ST-1	220	1,927,200	177.94	1,364,226
ST-2	220	1,927,200	191.42	1,529,428
ST-3	220	1,927,200	181.88	1,458,950
ST-4	220	1,927,200	176.71	1,435,890
ST-5	220	1,927,200	180	1,381,410
ST-6	220	1,927,200	165	1,422,001
Total	1,320	11,563,200	1,072.95	8,591,905

Table VIII: Year 2006 Power Generation Parameters

Unit	Installed Capacity (MW)	Installed Capacity (MWH)	Generated Capacity (MW)	Generated Capacity (MWH)
ST-1	220	1,927,200	130.91	1,052,177
ST-2	220	1,927,200	131.50	919,652
ST-3	220	1,927,200	126.52	918,879
ST-4	220	1,927,200	126.15	925,333
ST-5	220	1,927,200	130	992,133
ST-6	220	1,927,200	154	195,836
Total	1,320	11,563,200	799.08	5,004,010

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Table IX: Year 2007 Power Generation Parameters

Unit	Installed Capacity (MW)	Installed Capacity(MWH)	Generated Capacity (MW)	Generated Capacity (MWH)
ST-1	220	1,927,200	136.44	706,460
ST-2	220	1,927,200	144.62	1,014,622
ST-3	220	1,927,200	128.78	324,649
ST-4	220	1,927,200	123.00	880,338
ST-5	220	1,927,200	148	949,410
ST-6	220	1,927,200	0.00	0.00
Total	1,320	11,563,200	680.84	3,875,479

Table X: Year 2008 Power Generation Parameters

Unit	Installed Capacity (MW)	Installed Capacity (MWH)	Generated Capacity (MW)	Generated Capacity (MWH)
ST-1	220	1,927,200	145.83	1,052,164
ST-2	220	1,927,200	158.19	887,188
ST-3	220	1,927,200	128.78	324,649
ST-4	220	1,927,200	141.33	994,267
ST-5	220	1,927,200	155	1,128,188
ST-6	220	1,927,200	0.00	0.00
Total	1,320	11,563,200	729.13	4,386,456

III. DATA COMPUTATION

To calculate the total power outage cost (P_T) due to system down time for the ten years under review, we applied (1) to (5).

Firstly we calculate annual power outage cost (P_A) for the year 1999 using data in Table I. However to obtained P_A the following three parameters P_F, C_U and P_R are needed. Using (5) to calculate power factor (P_F) we have;

$P_F = 989.9/1{,}320 = 0.750$

The power factors for the year 1999 to 2008 is shown in Table XII

Also using (3) and (4) we calculated annual power reduction for the six turbine as demonstrated in Table XI below;

Table XI: Annual power reduction calculation

Turbine	Installed capacity(P_{IC})	Generated capacity (P_{GC})	Power generation reduction ($P_r = P_{IC} - P_{GC}$)
ST-1	1,927,200	1,672,562	254,638
ST-2	1,927,200	1,685,478	241,722
ST-3	1,927,200	1,359,482	567,718
ST-4	1,927,200	0.00	1,927,200
ST-5	1,927,200	1,205,435	721,765
ST-6	1,927,200	0.00	1,927,200
$P_R = \sum_{1}^{6} p_r$			5,640,243

C_U is assumed to be US$ 0.70 KWh

Therefore substituting values of P_F, P_R and C_U into (2) we have;

$P_A\,(1999) = 5{,}640{,}243 \times 0.750 \times 0.7 \times 1000$
$= \$2{,}961{,}127{,}575$

We followed the same procedure to obtain P_A (2000), P_A (2001)…… P_A (2008).

Finally we applied (5) to obtained total power outage cost for the ten years to be $24,186,569,250

Table XII: Annual capacity factor

Year	Installed capacity(MW)	Generated capacity(MW)	Capacity Factor
1999	1,320	989.9	0.750
2000	1,320	810.68	0.614
2001	1,320	986	0.747
2002	1,320	1,010.67	0.766
2003	1,320	852.34	0.646
2004	1,320	1,019.45	0.772
2005	1,320	1,072.92	0.813
2006	1,320	799.08	0.605

IV. RESULT AND DISSCUSSION

For the whole period of ten years under review, we critically look at the generated capacity against the installed generation capacity, results as shown in Table XIII and fig.1 below.

Table XIII: Power generation reduction

Year	Generation reduction	% reduction	% Available
1999	5,640,243	49	51
2000	6,543,552	57	43
2001	3,589,110	31	69
2002	4,691,696	41	59
2003	4,673,372	40	60
2004	3,494,840	30	70
2005	2,971,295	26	74
2006	6,559,190	57	43
2007	7,687,721	66	34
2008	7,176,744	62	38
Total	53,027,763	46	54

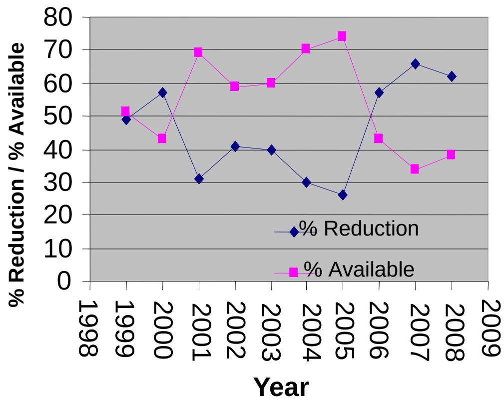

Fig. 1: Power generation reduction

The result revealed that there was power generation reduction between the range of 26 to 62 percent. Based on the installed capacity the station was expected to generate 115,632,000MWh of electricity from the year 1999 to 2008.

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However there was generation reduction of 53,027,763MWh amounting to 46 percent. This put the performance of the power station for the period under review at 54 percent.

Next we calculated the loss of revenue in dollars based on the power generation reduction of 46 percent. The result is as shown in Table XIV and fig. 2 below

Table XIV: Outage cost due to system downtime

Year	Power outage cost in dollars(P_A)
1999	3,109,238,329
2000	2,812,418,650
2001	1,876,745,619
2002	2,515,687,395
2003	2,113,298,818
2004	1,888,611,536
2005	1,690,963,985
2006	2,777,816,965
2007	2,776,804,825
2008	2,773,093,882
Total	24,334,680,000

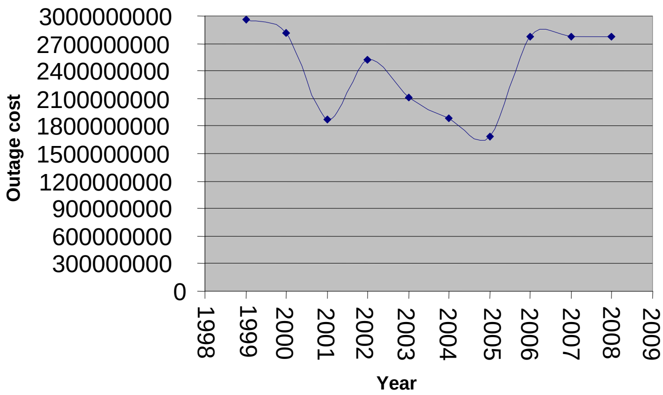

Fig.2: Outage cost in dollars due to system downtime

The result revealed that that from the year 1999 to 2008 the total outage cost due to power generation reduction of 46 percent is to the tune of $24,186,569,250.

From our findings the losses in generation is as a result of so many problems faced by the Power Station. Some of these problems includes; late release of capital subventions, inadequate working capital, ageing plant and machinery and poor maintenance programme.

V. CONCLUSION

From available records of Egbin Thermal power station, there appear to be no proper preventive maintenance programme in place. This and many other factors has resulted to the station generating power far below installed capacity. The analysis carried out revealed that the station was expected to generate a total of 115,632,000MWh of electricity from the year 1999 to 2008. However there was power reduction of 53,027763MWh amounting to 46 percent. Further investigation which is the main objective of this paper revealed that the 46 percent loss of production resulted to revenue loss of $24,186,569,250. This is no mean amount. This should be an eye opener to the Federal Government of Nigeria on the need to invest in the power sector in order to get good return on investment.

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