MAINTENANCE CULTURE IN ELECTRICAL POWER INDUSTRY IN NIGERIA: CASE STUDY OF AFAM POWER STATION

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ABSTRACT
The constant use of any production facility especially machines, equipment and tools increases its depreciation rate. Hence from time to time, repairs are needed, but repairs alone do not constitute good maintenance. Good maintenance policies prevent production interruption and losses in addition to the fact that it lengthens the service life of machines and equipment. This entails planned inspection, testing, cleaning, drying, monitoring, adjusting, corrective modification and repair of electrical equipment. This paper investigates the maintenance culture at Afam Power Station for selected years and the impact of such policies on installed machines and operational efficiency of the station. Results show that there are extensive deviations between maintenance policies guiding the station and actual practice. The resultant effect is that by 1997 only two generating units were working and the percentage performance of the station fell to 45.3%. Recommendations include the establishment of a good maintenance work documentation system, increased training programme for local manpower, privatization of the electric power industry among others.

INTRODUCTION
The maintenance of any engineering system consists of performing the following functions:

(a) Recognition or detection, location or diagnosis, correction, repair or replacement, and verification or checking of emergency failure of components or equipment.

(b) Setting up and performing scheduled periodic preventive inspections, replacements or repairs.

(c) Repair activities in a central facility on failed and replaced items arriving from different operating stations [1].

Unfortunately, the maintenance culture in the Nigerian society has not reached its expected standard. Maintenance practices are important for a variety of reasons. Its principal objectives include the following:

i. To extend the service life of the machinery [2].
ii. To ensure availability ad readiness of the machinery when needed.
iii. To obtain maximum returns on the investment by ensuring no unplanned interruption of production operations.
iv. To ensure safety of personnel and bystanders who use or come in contact with the machinery [3].

In order to achieve these objectives, there is the need for an efficient maintenance culture in all organizations in Nigeria.

Maintenance of any electrical equipment can be divided into two types namely: unscheduled maintenance and scheduled maintenance.

Unscheduled Maintenance is also known as emergency, curative or breakdown maintenance. This type of maintenance takes place when there is either accidental damage, malfunction of machinery or total breakdown of plant. Unscheduled maintenance causes huge economic losses to the production process of an electrical utility.

In most cases, it is practised because of unavailability of manpower, materials and equipment and poor maintenance attitude [4]. It proves to be more costly in the long run, time involving and creates poor public image of the power utility.

Scheduled Maintenance could take the form of preventive, routine maintenance, predictive or planned maintenance. Preventive maintenance is carried out before system failure occurs. Its objective is to prevent unexpected production nterruption due to machine troubles, accidents, mistakes and omissions on the part of such interruption [5]. It includes all scheduled or routine maintenance such as lubrication of machine parts, general overhauls, etc. Predictive or planed maintenance on the other hand, is the optimum use of maintenance to obtain the maximum economy and life of plant or equipment. The objective is to improve the life span and system performance [6]. Observation and estimation form its basic maintenance strategy. Hence it is based on work-study, production planning and control. It entails the prediction of the state of the plant and when it will cease to operate, in addition to the timing necessary for corrective action. Other important elements to be considered are level of machine vibration, noise level, temperature rise, pressure level and frequency fluctuation. These are needed for maximum convenience when equipment is on stream and is operating satisfactorily [7].

Maintenance is very important in order to ensure constant electricity supply and optimal efficiency of electrical machines. In addition, maintenance helps in early detection of equipment faults and thereby ensures minimal power outages and that the machine is in service throughout its life span. Unfortunately, the Nigerian power industry for decades has been characterized by frequent power interruptions, low customer voltages, constant machine breakdowns, etc. This has negatively influenced production costs in industry. An efficient maintenance policy will minimize these problems. Hence, this necessitates the need to investigate the maintenance culture of the Nigerian power industry using Afam power station as a case study.

The Objectives of the Study

The following research objectives were formulated to guide the study:

a) To ascertain the background characteristics of Afam power station with respect to number of generators, installed capacity per unit, transmission voltage level ad year of installation.
b) To obtain data on maintenance guidelines for the generating machines.
c) To find out the maintenance culture of Afam power station with respect to number of workable units and their performance
d) To find out deviations between the maintenance guidelines and actual practice for selected years.
e) To proffer policy recommendations to improve electric power generation in Afam and other power generating stations in Nigeria.

2. METHODOLOGY

2.1 Research Design

The descriptive survey research design was used for the study. Surveys are used for obtaining information concerning facts, opinions and behaviours using interviews, observations and such related methods. As this study deals with data collection on maintenance culture at Afam power station the choice of a survey is deemed fit for the study.

2.2 Data Collection Method

Primary data was collected through interviews ad observations. Secondary data was collected through archival sources (Afam Power Station Annual Reports for various years):

2.3 Data Analysis

Data was analysed using means, mean deviations and percentages. Data are presented in Tables.

3. RESULTS AND DISCUSSION

3.1 Historical Overview of Afam Power Station

The Afam power station is a thermal generating station located in Rivers State at about 40 kilometers away from Port Harcourt. It was installed with two machines in 1962. Its machines were increased to four in 1965 by the Brown Boveri Company, Switzerland. Its installed capacity by 1971 was 55.6 MW. It is connected to the National Grid Network. The power outputs from Afam I, II, III at 11.5KV are being dispatched from Afam I Master Control room after the voltage has been stepped up to 132KV. The 132KV switchyard feeds the urban cities of Port Harcourt and Aba. A 330KV switchyard is provided for Afam *N* machines. Presently its excess operating hours is approximately 80,000 hours which exceeds the recommended 16,000 running hours before an overhaul. Table 1. shows a summary of the gas turbines at the station.

Table 1: Composition of Afam Generating Station

Group	No. of Generators	Installed Capacity per unit (MW)	Transmission Voltage Level	Year of installation
AFAM I	2	13.6	132	1962
AFAM I	2	17.7	132	1964
AFAM II	4	23.9	132	1976
AFAM III	4	37.3	132	1978
AFAM IV	6	73	330	1982

The above mentioned generators are of the open cycle type. A new addition to the old generating units known as Afam V is presently very near completion with expected two generators each with an installed capacity of 130MW. In order to ensure maximum efficiency of machines at Afam power station, the Brown Boveri Company (BBC) of Switzerland has stipulated a chart to guide the maintenance of the plant and machines as shown in Table 2.

Table 2: Brown Boveri Company Table of Checks and Maintenance

	Variant	**Class A**	**Class B**	**Class C**
	Approximate time required	48 hours	98 hours	6 days (3 weeks)
	Interval	Every 4000 hours	Every 8000 hours	Every 8000 hours
	Operation	Combustion	Combustion Chamber	Combustion Chamber
1	Checks at standstill	Burner Swirl body Fuel nozzle Turbine blading Inlet and outlet	Burner Swirl body Fuel nozzle Turbine blading Inlet and outlet Safety equipment transformer Field resistance Inlet duck Compressor blading Lube oil	Burner Swirl body Fuel nozzle Turbine blading Inlet and outlet Safety equipment transformer Temperature at compressor inlet General temperature check All motors All control equipment
2	Overhaul	Batteries Coolers outside	Batteries Coolers outside Recording apparatus Fans Brushes and sliprings Flame detectors	Batteries Coolers outside All bearings Auxiliary gears High pressure pump Turbine and Compressor blading
3	Replacement			Electronic tubes
4	Measurements			Insulation resistance
5	Cleaning		All control panels All Insulators	Generator stator Winding
6	Checks at recommissioning	Acceleration characteristics Overspeed protection Temperature control Excess temperature protection	Acceleration characteristics Overspeed protection Temperature control Excess temperature production	Acceleration characteristics Overspeed protection Generator protection Temperature control Excess temperature protection Blow off valves

3.2 Maintenance Culture at Afam Power Station

The two major categories of staff involved in the maintenance of plant and equipment at Afam power station are the operational staff and the maintenance staff. Usually, the operational personnel make a note of all maintenance jobs that are taken care of by the maintenance staff. Both preventive and breakdown maintenance are adopted in this station. The maintenance of the generating units is supposed to follow the BBC maintenance list shown in Table 2. There are three classes known as A, B and C with different maximum operating times of the generating units before maintenance is due. An important aspect of the maintenance culture here is inspection, Machines are to be subjected to inspections at a regular basis according to the stipulations of the Brown Boveri Company Table of Checks and Maintenance cited in Table 2 but this is not strictly adhered to. The result is tha most units are overworked and thereby breakdowns occur (see table 6).

3.3 Status of Afam machines for selected Years

The status of Afam generators have been assessed for a period of five years (1993 to 1997) in order to show the maintenance culture of the power station. The results of the investigation are presented in tables 3 to 6.

Table 3: Status of Afam Power Station Machines as at December, 1993.

STATUS	UNIT	INSTALLED CAPACITY (MW)	REMARKS
AFAM I	GT.1	10.3	Defective lube oil cooler fan maintenance
	GT.2	10.3	Retired
	GT.3	17.5	Damaged Exciter and Gen. Bearings
	GT.4	17.5	O/H suspended, No spares
AFAM II	GT.5	23.9	*Operational
	GT.6	23.9	*Operational
	GT.7	23.9	Lack of Exciter carbon brushes
	GT.8	23.9	Turbine blade failure on 3/4/88
AFAM III	GT.9	27.2	O/H suspended since 1986
	GT.10	27.2	Extraction of rotor suspended
	GT.11	27.2	Work on hydraulic oil system in progress
	GT.12	27.2	*Operational
AFAM IV	GT.13	75	*Operational
	GT.14	75	*Operational
	GT.15	75	Awaiting rehabilitation
	GT.16	75	Awaiting rehabilitation
	GT.17	75	*Operational
	GT.18	75	*Operational

Legend: *Indicates units that are working; OIH = overhaul. Source: [8].

Table 4: Status of Afam Power Station Machines as at December, 1994.

STATUS	UNIT	INSTALLED CAPACITY (MW)	REMARKS
AFAM I	GT.1	10.3	Faculty Gas regulating valve
	GT.2	10.3	Retired
	GT.3	17.5	Damaged Exciter and Gen. bearings
	GT.4	17.5	O/H suspended, No spares
AFAM II	GT.5	23.9	Turbine blade failure
	GT.6	23.9	Stator Earth fault completed
	GT.7	23.9	Starting problems after 8000 hrs inspection
	GT.8	23.9	Turbine blade failure on 3/4/88
AFAM III	GT.9	27.2	O/H suspended since 1986
	GT.10	27.2	Extraction of rotor suspended
	GT.11	27.2	Hydraulic oil system failure
	GT.12	27.2	Synchronizing fault
AFAM IV	GT.13	75	*Operational
	GT.14	75	Problems after 4000 hrs inspection
	GT.15	75	Awaiting rehabilitation
	GT.16	75	Awaiting rehabilitation
	GT.17	75	*Operational
	GT.18	75	*Operational

Legend: *lndicates units that are working; *O/H* = overhaul. Source: [8].

Table 5: Generating Station plant Status as at December, 1995.

Units	Installed capacity	Date installed	Capacity	Date of last O/H	Hrs run before O/H	Evaluation hrs run to date	Hrs run since O/H	Recommended hrs for O/H	Excess hrs run	Remarks
1	10.3	1962	8	April 1984	23991	57238	33247	16000	17247	Overdue for O/H
2	10.3	1962	-	-	-	-	-	-	-	Scrapped
3	17.5	1964	-	Sept. 1983	63776	84109	30333	16000	14333	Overdue for O/H
4	17.5	1964	-	Dec. 1979	8526	52013	43487	16000	27487	Overdue for O/H
5	23.9	1976	-	Sept. 1983	47405	107034	59634	16000	43634	Awaiting rehabilitation
6	23.9	1976	18	Aug. 1983	40499	89834	49335	16000	33335	Overdue for O/H
7	23.9	1976	18	Jan. 1984	43352	101202	57850	16000	41850	Overdue for O/H
8	23.9	1976	-	June 1985	41818	57380	15561	16000	-	Awaiting rehabilitation
9	27.2	1978	-	Sept. 1985	42802	42802	-	16000	-	Overdue for O/H
10	27.2	1978	-	Oct. 1982	30441	54845	24404	16000	8404	Overdue for O/H
11	27.2	1978	5	May 1981	18506	75568	57002	16000	41002	Overdue for O/H
12	27.2	1978	10	Nov. 1982	22132	75718	53586	16000	37586	Overdue for O/H
13	75	1982	40	Oct. 1985	16885	87904	70919	16000	54919	Overdue for O/H
14	75	1982	40	Mar. 1985	12375	77904	65529	16000	49529	Overdue for O/H
15	75	1982	-	Sept. 1983	5049	40257	35298	16000	19208	Awaiting rehabilitation
16	75	1982	-	May 1984	9342	60215	50873	16000	34873	Awaiting rehabilitation
17	75	1982	65	Aug. 1993	30923	44590	13667	16000	-	* Not yet due
18	75	1982	65	Dec. 1992	20610	37792	17182	16000	1182	* Not yet due

* Indicates the non workable units; *O/H* overhaul Source: [8].

Table 6: Stat us of Afam Machines as at December, 1996.

Status	Unit	Installed Capacity (MW)	Remarks
AFAM I	GT.1	10.3	Unavailable since February 1994 due to worn out bearings and hydraulic system.
	GT.2	10.3	Scrapped
	GT.3	17.5	Unavailable since February 1994 due to worn out bearings
	GT.4	17.5	Unavailable since February 1994 due to worn out bearings
AFAM II	GT.5	23.9	Unavailable since February 1994 due to turbine blade failure. Due for major overhaul since 1983.
	GT.6	23.9	* Available for 15MW and in service. Overdue for major overhaul since 1983.
	GT.7	23.9	* Available for 15MW and in service. Overdue for major overhaul since 1983.
	GT.8	23.9	Unavailable since 1988 due to turbine blade failure. Overdue for major overhaul.
AFAM III	GT.9	27.2	Unavailable. Overhaul abandoned by contractors since 1986.
	GT.10	27.2	Out of service since 1989 due to high vibration on the generator rotor.
	GT.11	27.2	Unavailable since 1993 due to hydraulic system oil failure.
	GT.12	27.2	Safety oil pressure trips often. Due for overhaul since 1987.
AFAM IV	GT.13	75	Unavailable since 1996 due to compressor blade failure. Due for overhaul since 1987.
	GT.14	75	Due for overhaul since 1987. Available and in-service but derated to 40MW due to deteriorated heat shield.
	GT.15	75	Unavailable since 1989 due to turbine blade failure.
	GT.16	75	Unavailable since 1992 due to compressor blade failure.
	GT.17	75	Unavailable since 1996 due to compressor blade failure.
	GT.18	75	Unavailable since 1996 due to compressor blade failure.

* Indicates the units that are working. Source: [8].

Table 7: History of Afam generating plans from 1962 to 1997

Unit	Date of Commission	Date of O/H Since Date of Commission	Manufacturer's Specification for O/H	Cumulative Running Hrs After O/H	Remarks
GT.1	1962	April 1984	16000	57238	Worn out bearings since 1992
GT.2	1962	-	16000	-	Scrapped in 1979
GT.3	1964	Sept. 1983	16000	8410	Worn out bearing since 1990
GT.4	1964	Dec. 1979	16000	52103	Unavailable due to lack of spare parts
GT.5	1976	Sept. 1983	16000	107035	Turbine blade failure since 1994
GT.6	1976	July 1983	16000	98791	Awaiting supply
GT.7	1976	Jan. 1984	16000	109051	Awaiting supply
GT.8	1976	June 1985	16000	57381	Turbine blade failure since 1988
GT.9	1978	Sept. 1985	16000	42802	Overhaul suspended due to lack of spare parts since 1986
GT.10	1978	Oct. 1982	16000	54845	High vibration of generator rotor since 1988
GT.11	1978	May 1981	16000	76401	* In-service
GT.12	1978	Nov. 1982	16000	9812	* In-service
GT.13	1982	Oct. 1985	16000	88419	Compressor blade failure since 1986
GT.14	1982	Mar. 1985	16000	86762	Compressor blade failure since 1986
GT.15	1982	Sept. 1983	16000	40257	Compressor blade failure since 1986
GT.16	1982	May 1984	16000	60215	Compressor blade failure since 1986
GT.17	1982	Aug. 1993	16000	56143	Compressor blade failure since 1986
GT.18	1982	Dec. 1992	16000	38399	Compressor blade failure since 1986

* Indicates workable units; *O/H* overhaulSource: [8].

Table 8: Generated Energy Cost at Afam Power Station from 1993 to 1997.

Year	**Total Energy Generated Per Year (MWH)**	**% Average Station Load Factor Per Year**	**Average Cost Per Unit Per Year (Naira)**	**Cost of Energy Generated Per Year (Naira)**
1993	1,293,890.06	69.4	5.79	7,491,626.57
1994	650,431.02	48.4	3.84	2,497,655.81
1995	774,868.06	58.6	4.59	3,556,646.87
1996	542,204.09	53.3	4.59	2,488,720.49
1997	350,276.01	45.3	5.36	1,877,479.90

Data from Table 3 shows that seven out of 18 units were working by 1993 but by 1994, only 3 units were working according to information on Table 4. A marked improvement occurred in 1995 when the machines were maintained. Five of the machines started working. However, by 1996 only 4 machines were working. The situation got worse after 1996. Only 2 machines were operating in 1997. Hence, the performance of the power station as derived from the tables is summarized in Table 9.

Table 9: Summary of Workable Units ad Performance.

Year	No of Workable Units	Total Energ Generated (MWH)	% Average Station Load Factor
1993	7	1,293,890.06 ,	69.4
1994	3	650,431.02	48.4
1995	5	774,868.06	58.6
1996	4	542,204.09	53.3
1997	2	350,276.01	45.3

Table 8 shows that the amount of megawatts generated is a function of the behaviour of the machines. More megawatts were generated ad more money realized with healthier machines. Table 9 shows the average percentage performance of the units per year. It is evident that the higher the number of functional machines the higher the percentage performance. For example in 1993, 7 units were working; 69.4% was registered as the percentage performance of the power station. In 1999, 3 units were working with 48.4% as the percentage performance. 58.5% was the percentage performance in 1995 with 5 workable units. In 1996, 4 units operated with 53.3% as the percentage performance. In 1997, 2 units were working, and its percentage performance was 45.3% for that year. These values show extensive deviations from the stipulations of the Brown Boveri Company on maintenance practices for optimal efficiency of machines. This shows that preventive maintenance practice was at its lowest ebb at the Afam Power Station during the period under consideration. The resultant effect is low capacity utilization, power outages due to overworked machines and explosions such as the September 12, 1997 explosion at the power station.

4. CONCLUSIONS AND RECOMMENDATION

4.1 Conclusions

An investigation of the maintenance culture at Afam power generating station from 1993 to 1997 has been carried out. Ineffective maintenance culture at the station has given rise to very long downtimes and subsequent idle machines. This has led to a drop in the magnitude of generated power from the station in the period of the investigation. Delays in making funds available for maintenance purposes was identified as a major problem in ensuring a smooth running of the station. The study showed that there was no maintenance management section in the power station that would be useful for keeping of maintenance records and data.

4.2 Recommendations

In order to improve electric power generation at Afam electric power station and other generating stations in the country the following recommendations are suggested:

i. The volume and complexity of maintenance work in the modem industrial setting necessitates that it should be planned and scheduled so that necessary maintenance work can be carried out systematically and conscientiously. It is of vital importance to establish a good maintenance work documentation system that will provide the basis for information input into the planning and scheduling process. This will involve short and long range planning. Such plans will include modalities and provisions for changes in equipment and facilities, changes in production equipment due to obsolesce, increased mechanisation automation, higher machine speeds and technological improvement to support production in the future.

ii. The Nigerian government needs to increase budgetary allocations for the power sector so that maintenance of power systems will be more efficient.

iii. In addition, it is pertinent to increase the motivation of staff working in power stations through welfare schemes and safety net programmes so as to elicit maximum worker productivity and commitment in the discharge of duties.

iv. Increased training programs are also necessary for local manpower. This will equip them to minimize errors in handling of equipment and impart maintenance skills in workers. Such training programmes are more effective when organized intermittently as opposed to ad hoc measures that characterize the training programmes of various establishments.

v. Finally, increased effort at privatisation of the electric power increase competition among power producers, and make for more efficient handling of equipment and improved maintenance practices in the power sector.

REFERENCES

1. Annan, E. Techniques for optimal maintenance scheduling. Unpublished manuscript, University of Nigeria Nsukka, 1997.

2. Etinger, B. and Barber, H. *The transmission and distribution of electrical Energy* Houdder and Stoughton, London, 1980.

3. Odigboh, E.U. agricultural machinery maintenance management in Nigeria: Problematic issues and possible remedies. Resource paper presented at PTF National Workshop on Facility Management for Farm Power and Machinery, Abuja, October 23, 1997.

4. Adegboyega, A. Maintenance importance in a power station. delivered at Kainji Power Training School, 1998.

5. Clifton, R.N. *Principles of Planned Maintenance*, Edward Arnold, London, 1974.

6. Okah-Avae, B.E. The Science of Industrial Machinery and System Maintenance, Spectrum Books Ltd., London, 1995.

7. Vinogradou, N.V. *Electrical Apparatus and Appliances: Maintenance and Repair* (The Industrial Electrician), Mir Publishers, Moscow, 1970.

8. Afam Power Station *Annual Reports* 1993 to 1997.