RELIABILITY OF THE AFAM ELECTRIC POWER GENERATING STATION, NIGERIA

BY

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ABSTRACT.

Today's economic climate requires that each industry aim at achieving maximum production capability while minimizing capital investment e.g. in the maintenance function. This means finding ways to maximize equipment reliability and up-time and extend plant and equipment life through cost effective maintenance. This paper surveys the performance of gas turbine plants in Afam Thermal Power Station. The findings show that the impact of lost generation (through non-availability) exceeded within a few years, the initial purchase price of the power plants and associated equipments.

ABBREVIATIONS

A	Availability
CMMS	Computerised maintenance-management system
GT	Gas turbine
MTBF	Mean time between failure
MTTR	Mean time to repair
NEPA	National electric power authority
PM	Preventive maintenance
R&M	Reliability and maintenance
RCM	Reliability centred management
TAM	Total asset management
TPM	Total productive maintenance
TPQM	Total planned quality maintenance
TQM	Total quality management

RELIABILITY AND OPERATING AVAILABILITY

Reliability is the capability of an asset to continue to perform its intended function. It is normally measured as the mean time between failures (MTBF) for each system (Dunn, 2002).

Reliability-centred maintenance is a process used to ensure that any physical asset continues to do what it is designed and instructed to do. Reliability engineering is concerned with predicting and avoiding each failure as well as assessing the cost if the failure is allowed to occur.

Staff must ensure that the equipment is designed and/or modified to improve maintainability, which ongoing maintenance technical problems are investigated, and that appropriate corrective and improvement actions are taken (Dunn, 2002).

The schedule compliance is one of the key indicators often used to monitor and control maintenance. It is defined as the number of scheduled work orders completed in a given time period (normally one week), divided by the total number of scheduled work orders for that: it is normally expressed as a percentage, and will always be less than or equal to 100%. Alternatively, it can be expressed as a percentage of actual capacity utilization to the actual or installed capacity over a period of one year. The scheduled restoration task is a maintenance task to restore a component at a specified, pre-determined frequency, regardless of the condition of the component at the time of its replacement. An example would be the routine overhaul of turbine after every 170,000 operating hours. The frequency with which a scheduled restoration task should be performed is determined by the useful life of the component.

The total productive maintenance, TPM programme, emphasizes the production operators' involvement in equipment redesign, maintenance and continuous process improvement. Value engineering of a new asset is used to systematically ensure that the user's requirements are met, but not exceeded. It consists primarily of eliminating perceived "non-value-adding" features of new equipment. An emerging trend in the strategy to maintain the reliability of equipment is known as total asset management, TAM, which is an integrated approach to asset management incorporating elements such as Reliability-Centred Maintenance, RCM, Total Productive Maintenance TPM, Design for maintainability, Design for Reliability, Value engineering, Life-Cycle Costing, Probabilistic Risk Assessment and others, to arrive at that optimum Cost-Benefit-Risk asset solution to meet any given production requirements (Dunn, 2000). This approach must adopt the total planned quality maintenance, TPQM, which is a management philosophy for integrated maintenance that advocates planning all maintenance (i.e., preventive, predictive, corrective, and automatic self-fulfilling), as well as the control of quality in maintenance. Maintenance Plan improvement may consist a computerized maintenance-management system CMMS, with all modules active, enabling the company to track scheduling, parts supply, planning, preventive maintenance programmes (PM,) environmental and safety compliance, as well as statistical maintenance control functions and performance expectations, product quality, customer service, economy and efficiency of operation, control, containment, comfort, protection, and compliance with environmental regulations, structural integrity and even the physical appearance of the asset are also concerned

Failure data and repair time data can be converted into statistical format using Win Smith Weibull software for use in reliability calculations, (Fulton, 2000) Reliability models,

using actual failure data and repair times enable one to predict a system's operational availability as well as its reliability, maintainability, and other operating behaviour (Barringer, 2000). Some of the failure information arises from simple arithmetic calculations and other data follow the preferred method using Weibull databases (Abernethy, 1999). The frequency of failures and their costs are influenced by the original design and construction of the system, the quality of its installation, how carefully the system was used and how well it was maintained. Monte Carlo simulations will enable one to find how costs will vary with time and the various influential factors (Barringer, 1999). The reliability model enables one to predict what's affordable and identifies undesirable alternatives. Effectiveness is influenced by the availability, reliability, maintainability, and capability of the system to perform.

Often there are pertinent questions for process reliability:
- What's the availability of your process?
- What's the reliability of your process?
- What causes process failures?
- How predictable is your process?

Reliability analysis of the process data helps answer these questions.

Among the causes of utilization losses, (Barringer and Roberts, 2002) are: (1) excessive system-stress (e.g. of temperature, pressure, flow, chemical concentration); (2) late starts/early quits; (3) lack of concern for long-term optimization; (4) too frequent change of process aims; (5) lack of a statistical process control; and (6) use of analogue rather than digital control.

Problems should be identified with time and money so that everyone can understand them-then fix them on a priority basis so that the business is more profitable. The process needs a high availability (i.e. a high% of uptime) free from failures, predictable output and removal of hidden problems.

RCM entails asking the following questions:- (1) What are the functions and associated performance standards of the asset in its present operating context? (2) In what ways does it fail to fulfil its functions? (3) What causes each functional failure? (4) What happens when each failure occurs? (5) In what way does each failure matter? (6) What can be done to predict or prevent each failure? (7) What if a suitable proactive procedure cannot be identified?

Electric Power Projects round the world, except Nigeria, are reliable, low cost kilowatt hours, address specific customer requirements, coordinates technology enhancements and emergency response, environmental compliance, large-scale modernization projects, and risk management. Failures in electric power stations result in downtime, production losses and economic losses as well.

Maintenance practices in Nigeria still leave much to be desired with respect to breakdowns, unscheduled maintenance, and long downtimes. Maintenance is generally regarded in Nigeria as an undesirable cost-generating activity rather than one resulting in improved reliability, greater profitability and higher productivity.

In Nigeria, maintenance is still too often neglected and so the resulting associated costs as a percentage of the total operational cost keep rising. The most notable problem is the absence of an effective and efficient maintenance process. The first step should be to audit the existing maintenance system, to identify and measure the weaknesses in the existing system and then a medium-range plan devised to improve he system.

MAINTENANCE PARAMETERS

An artefact's reliability is the probability that it will perform the function for which it is designed under specified conditions for a predecided period of time. Reliability relates to the frequencies of outages.

$$\text{Reliability, } R(t) = \exp(-t/\text{MTBF}). = \exp(-\lambda t) \tag{1}$$

where t = period of failure

MTBF = $1/\lambda$ = total operating time/number of failures.
MTTR = τ = total outage time/number of failures = $1/\mu$
When these two factors are known for any given system or component, then the availability (A) is expressed as:

$$A = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} = \frac{1}{1 + \lambda\tau} = \frac{\text{Uptime}}{\text{Uptime} - \text{Downtime}} \tag{2}$$

Where λ = failure rate i.e. number of failures/unit time
$\quad \tau$ = duration of outage.
$\quad \mu$ = repair rate = $1/\tau$.

$$\text{Maintainability } (Mt) = \exp(-t/\text{MTTR}) = \exp(-\mu t). \tag{3}$$

$$\text{Utilization (efficiency)} = \frac{\text{Actual work hours}}{\text{Max. potential hours of operation} + \text{delay hours}} \tag{4}$$

AFAM THERMAL POWER STATION

This is the first major gas-turbine station built in Nigeria: it is located in the oil/natural gas region of the Niger Delta, because of the large reserves there of these natural resources. The station with its auxiliary units were built and installed by Brown Boveri. The first phase, Afam 1 was constructed and commissioned in 1963. It consisted of four-generating units ($GT_1 - GT_4$) each with installed capacity of 10.3MW. However, the local economic growth experienced in the seventies necessitated four additional generating units, each with an installed capacity of 23.9MW, being commissioned in 1976 and known as Afam II. This was followed by four gas turbines of 27.5 MW each,

commissioned in 1978 and known as Afam III. In 1982, six generating units, with installed capacity of 75 MW each were added to the station. In 2002, Afam V was commissioned, with two generating units each of installed capacity 138MW.

This rapid growth has ensued despite enormous technical problems with the individual generating units and the auxiliaries. These have caused forced or emergency outages, long or delayed downtime, high cost of power generation and erratic power supplies from the station. Maintenance cost, in the power industries in Nigeria amount to approximately 25-35 percent of the total production cost i.e. much more than that for fuel. The increasing electricity demand, the increasingly competitive environment and the recent deregulation of Nigeria's electricity supply sector are resulting in increased competition among the independent power producers. To survive, suppliers must reduce maintenance costs prioritize maintenance actions, and raise reliability.

PLANT CONDITIONS AND MAINTENANCE ATTITUDES IN AFAM POWER STATION.

From a recent survey, there is evidence that the power station performs disappointingly compared with world-class operations. A written maintenance policy and strategy needs to be published. A co-ordinator for planning the work orders, to decide the resources allocations, training, and maintenance executions needs to be appointed. The preventive maintenance, PM, route, procedures and intervals between maintenance are not well defined. Poor plant history records make it difficult to retrieve the PM history especially for the older plants. A maintenance-culture/commitment via team-based rewards and recognition should be introduced together with employee empowerment. To date, the total power available is 430 MW from the Afam Thermal Power Station even though the system was designed to provide more than 990 MW.

RELIABILITY AND AVAILABILITY CALCULATIONS

The first step should be self-auditing to ascertain strengths, weakness and opportunities. The application of R&M principles in Afam Thermal Power Station plants/equipments requires that the system/component availability be defined in terms of Mean-Time-Between-Failures, MTBF and Mean-Time-To-Repair, MTTR. MTBF is the reciprocal of the frequency of failures and MTTR is related to the duration of outages. By definition, availability (A) is related to both frequency and duration of outages (equation 1)

Thus, the availability goal can be converted into reliability and maintainability requirements in terms of acceptable failure rates and outage hours for each component as explicit design objectives provided these two factors, MTBF and MTTR, are known for any given system or component. Then the availability of the system or component can be expressed as shown in equation (1):

As an example: if
Total outage hrs / yr =900hrs.

No. of failures / yr =15
Then

MTTR = 60hrs.
MTBF = 7860 / 15 =524

$$A = \frac{MTBF}{MTBF+MTTR} = 0.896$$

Unavailability = 1-A = 1-0.896 =0.104

Annual power generation in 2002 = 430 x 8760 mWh
Total Installed capacity = 990.8 x 8760 mWh.
Capacity factor = 430/990.8 =0.44
Annual generation reduction (on 430MW) = 430 x 900

If the cost of power replacement is US$ 0.60/kWh

Then annual outage cost due to turbine failures = $ 900 x 430 x 0.44 x 1000 x 0.6

This cost can be added to the costs of maintenance and installation to obtain an overall plant operating costs.

CONCLUSIONS

From the available records of the Afam Power Station, there appears to be no standards or benchmarks, but rather unreliable inconsistent estimates of probable job duration. There is no procedure for reporting performance/productivity, and maintenance costs, PM programmes, breakdowns, etc. There are no control data presented through graphs and charts.

Better aims and specific targets are needed for the Afam power station to improve maintenance management systems and productivity. This should be based on a new maintenance paradigm that will improve maintenance control and PM activities. Performance measures are necessary tool for tracking progress, while some may be used in benchmarking or assessment (Al-Muhaisen and Santarisi, 2002).

The managers must formulate wise strategies, make decisions and monitor progress against plans by collecting, retrieving and analyzing data.

Reliability models using actual data and repair times give system availability, reliability, maintainability, and other operating system details which allow estimations of costs and trade offs (Barringer 2000).

To reduce downtime and achieve high production capabilities, the aim should be to find ways to increase equipment reliability and extend the equipment's life through cost-effective maintenance. To achieve these, NEPA must move away from the traditional

reactive maintenance mode to proactive maintenance and management philosophies. There should be maintenance processes that fully address TQM and TPM operating modes. Such change requires a complete shift to a Total Planned Quality Maintenance (TPQM) approach, which is a maintenance and management philosophy that advocates planning all maintenance (i.e. preventive, predictive and corrective), as well as the control of quality in maintenance operations.

Failure databases derived from world-wide information will be required within plants, within divisions, and within companies Keeping-local data in Weibull databases should provide details for life-cycle costing by end-users to make better decisions about grades of equipment purchased and how failures affect long-term operating costs (Barringer 1996). Optimizing reliability starts at the front end of the design process and works through to the life-cycle costing using failure data. Optimizing the cost of unreliability starts after plants are built and effectively reduces problems built into the system by considering trade off in corrective actions. Hence, reliability optimization process starts by collecting age-to failure data and costs associated with the failures, sharing failure data with the supplier partnerships, using the data to solve problems in the plant and to use such failure data to design more cost effective plants in the future.

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