Engineering and Technology Journal e-ISSN: 2456-3358

Volume 08 Issue 11 November -2023, Page No.- 3002-3010

DOI: 10.47191/etj/v8i11.09, I.F. – 7.136

Availability and Reliability Indices: A practical Approach for Afam thermal Plant Assessment and Improvement

W. A. Akpan[1], S.I. Beshel[2], N. I. Effeng[3], K.E. Akpan[4]

[1,2,3,4] Mechanical and Aerospace Engineering Department, University of Uyo, Nigeria.

ABSTRACT: Mechanical integrity and risk analysis for power stations are often based on few failure data. The risk issue is to reduce and forecast future failure and corrective actions taken to mitigate down time. The power station has been acquiring equipment failure data for many years. Seldom is the data analyzed in a scientific manner, and rarely the acquired data used to solve their maintenance problem. The objective of this paper is to mine piles of existing data and how age to failure data can be in a thoughtful manner and used for reliability and availability purposes. Weibulll graph is used for the failure data.

KEYWORDS: Reliability data, failure prediction, overhaul intervals, Afam power station. Availability, maintainability.

INTRODUCTION

Changes have occurred at all levels from obviously technical shift as equipment and systems become increasingly complex, to strategy transformation in the way we understand failure and rationale used to develop planned maintenance activities. Loss of production through equipment failure has become unacceptable leading to work on prevention of failures before they occur. As equipment get older, they wear out and become more likely to fail. Using the model it is believed that failures would be avoided if equipment was maintained before items wear out ie planned intervention at the right time will prevent failures. The use of maintenance performance indicator, the ratio of planned and break down maintenance could be helpful. If the likelihood of item failure increase with age, then planned intervention before the failure should reduce the number of failures that occur. Using this model suggests thus if we continue to see failures then we have not intervened early enough, ie we do not know the right age. Hence, the effectiveness of the strategy will be to measure the amount of planned and unplanned maintenance. This may not take the technical characteristics into account.

Reliability is a function of time. Reliability Engineering is concerned with predicting and avoiding failures, which is a strategic task. Maintenance engineering is concerned with quickly restoring failure-free operation during a given interval, that is , a measure of success for a failure free operation[1] Both reliability engineering and maintenance engineering have roots in each other’s territory and thus must know about each other roles, responsibilities, and tools [2] Improvements and justifications are based on financial details and alternative. This requires knowing: when things will fail, how things will fail and conversions of failure and to provide facts for life-cycle costs comparisons which will help to decide the lowest long-term cost of ownership driven by a single estimator, the Net present value (NPV). This will convert hardware issues and alternative into money issues.

Knowing about time to failure and failure model are found by alternative engineering. Preventing failures cost money and repairing failure cost money, however one is safer and cheaper than the other. The cost of failures mist also include gross margin losses from production outages and cut tracks. Also the mode of failure provides information about severity of failure. The death of most equipment must be analyzed from small samples using a very practical reliability technique of Weibull analysis for each failure mode [3]. In many cases a very simple arithmetic technique of mean time before failure (MBTF) or mean time to failure (MTTF) is frequently used as a precursor reliability of equipment considering mixtures of failure modes that occur. Without tools for defining life/death of equipment, it is difficult to costs for life cycle decisions [3]

Current Maintenance Efforts

Afam thermal power station is one of the gas thermal stations situated in the oil rich region of the Niger Delta. Because of electric power constitute a major component of any economy, the importance of the power supplies to Port Harcourt and environs, which is the operational base of major oil companies can hardly be emphasized . Although there is additional new plants to the old ones, but the problem of power failures will continue if immediate efforts are not taken to finding lasting solution to the maintenance problems facing the power station.

However, rapid rising of power demand in Nigeria and the unfortunate erratic power supply have stimulated a great deal of interest in finding ways to improve the reliability and availability of both new and existing old plants. Other factors being to: restore confident to the consumers, safety and environmental considerations. It seems that all attempts to find a permanent solution for thr maintenance practices is the total productive maintenance, TPM and reliability centered maintenance RCM. For maintenance management, a comprehensive, realistic approach for improving asset performance is the uptime. The two maintenance practices, the TPM and RCM have led to increasing interest within the industry in the last decades, which offer a path to long term continuous improvement rather than the quick fix. The TPM is a manufacturing led initiative that emphasizes the importance of people, a ‘can do’ and continuous improvement philosophy and involving both the maintenance and production staff working together. In essence, TPM seeks to reshape the organization to liberate its own potentials. TPM is concerned with the fundamental rethink of business processes to achieve improvement in cost, quality and speed, etc. It encourages radical changes such as multi-skilled workforce, rigorous reappraisal of the way thing are done, empowered team.

The maintenance approach best suited to an item can be determined by RCM methodology, it provides the requirements for determining maintenance requirement of any physical asset in its operating context, with the primary objective of preserving system function cost effectively. Present effort in maintenance practices is the total productive maintenance and reliability centered maintenance [4],[5] . RCM identifies systems functions and functional failures as well as failure mode and effect analysis.

This practices are in advanced countries , but in Nigeria, the downtime mode of practice is still widely used. In almost all the industries in Nigeria, there is still no serious attempts to switch uptime strategies. It is therefore the purpose of this paper to look for solutions, using the downtime maintenance practice, using the failure mean downtime and planned maintenance data

RELIABILITY MODELS AND THEORY

[6] gave shortlist of Reliability engineering principle tools. The tools are used for predicting failures and finding cost effective alternatives.

Failure and failure costs can be influenced by operating conditions, and maintenance conditions. The Monte- Carlo simulation model is used for finding how costs will influence the different grades of failures. The Monte-Carlo technique uses random numbers and spreadsheet to solve the problem. Reliability models show what are affordable and less desirable alternatives. Using actual failure data the repair times give system reliability, availability, maintainability and capability of the system to perform.

Availability

Availability deals with the duration of uptime for operations and is a measure of how often the system is alive and well. It is expressed as:

A=uptime/(uptime+downtime). The uptime refers to a capability to perform the task and downtime refers to not able to perform task.

When availability is known, the up time foe a given interval can be estimated, eg, an equipment is desired to operate sound the clock (total time in a year is 8760 hours), and it has availability of 98%. The process uptime is 0.98x 8760=8584.8 hours/year and downtime of 0.02x8760=175.2 hours/year. Availabilty+unvailabiltiy=1. A system can be available(ready for service) and reliable absence of failures for designated time interval to produce effective result. Unvailability occurs when the equipment is down foe periodic maintenance and repairs.

Reliability

Reliability deals with reducing the frequency of failure over a time interval. Reliability is a measure of probability of failure free operation during a given time interval, ie it is a measure of success for a failure –free operation. It can be expressed as:

$$R(t) = \exp(-t / MTBF) = \exp - \lambda t \quad (1)$$

Or expressed in Weibull terms as:

$$\exp(-t / \eta)^{\beta} \quad (2)$$

where λ is constant failure rate and MBTF is mean time between failure. MBTF is a yardstick for reliability, which measures the time between systems failures for exponentially distributed failure modes. MBTF is a basic figure of merit for reliability and failure rate λ

Is the reciprocal of MBTF .A system reliability is measured by long failure free operation. Long periods of failure-free interaction results in increased productive capability while requiring fewer spare parts and less manpower for maintenance activities, which results in lower costs. For the vendor of the equipment, reliability is measured by completing a failure-free warranty period under specified operating conditions with few failures during the design life of the product.

Improving reliability often occurs by reducing errors from people / procedures and those changes can usually be made at small costs. Reliability can also be improved by purchasing high quality/cost equipment. Reliability improvements being expectations for improving availability, decreasing downtime and lower maintenance costs, improves secondary failure costs and results in better chances for making money since the equipment is free from failures for longer periods of time.

Maintainability

Maintainability is defined as the relative ease and economy of time and resources with which an item can be retained in , or restored to a specific condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, a t each prescribed level of maintenance and repair[7] It is a designed function, Design for maintainability requires a product that is serviceable-must be easily maintained and supportable, must be cost effectively kept in or restored to make usable condition, and may include reliability-absence of failures.

Supportability has a design feature involving testability (a design characteristics that allow verification of the status to be determined and faults within an item to be isolated in a timely and effective manner such as can occur with built-in-test (BIT) so that new item can demonstrate its status(operable, inoperable or degraded) and similar conditions for routine trouble shooting and verification after the equipment has been restored to useful conditions after maintenance. Maintainability is also how long equipment will be down and unavailable. Highly trained and empowered workforce and s responsive supply system which paces the spee of maintenance can achieve for minimum downtime. Reliability and maintainability are considered complementary disciplines from the inherent availability equation. Inherent availability looks at availability from a design perspective.

$$Ai = MBTF/(MTBT + MTTR) \quad 3$$

If mean time between failure or mean time to failure is very large compared to the mean time to repair, MTTR or mean time to replace, then there will h be high availability. As reliability decreases ie MTTR becomes smaller, better maintainability ie shorter MTTR is achieved. The operational availability , A_o is a practical system:

$$A_o = MTBM/(MTBM + MDT) \quad 4$$

where MTBM is the mean –time between maintenance, and MDT is mean downtime.

The MTBM include all corrective and preventive actions (compare to MBTF which only accounts for failures). The MDT includes delays (compared to MTTR which only addresses repair time) including self imposed downtime for preventive maintenance (PM) although it is preferred to perform most PM actions while the equipment id operating, $A_o < A_i$. Increasing MTBM by one order of magnitude or decreasing availability from 85% to 90% requires improving MTBM by less than approximately ¾ order of magnitude.

A key maintainability figure of merit is MTTR and a limit for the maximum repair time. Quantitatively it refers to the ease with which hardware or software is restored to a functioning state. It has probabilities and is measurable base on the total downtime for active ,verification , testing that the repair is adequate delays for the logistic movements and administrative delays. It is often expressed as:

$$M(t) = 1 - \exp(t/MTTR) = 1 - \exp(-\mu t) \quad 5$$

where μ is constant of maintenance rate, MTTR is the mean time to repair, the arithmetic average of repair time.

Capability

Capability deals with productive output compared to inherent productive output. This index measures the system capability. Capability =utilization Efficiency. Productivity is the ratio of time spent on productive efforts to total time consumed.

Efficiency measures the productive work output to work input as an example. If the efficiency is 80% because of the wasted labour and scrap generated and utilization is 82% , because the operation is 300 days instead of 365 days. The capability is 0.8x0.82=0.656%. Capability measures how well the production activity is performed compared to the datum

Effectiveness

Effectiveness is a measure of value and it varies from zero to unity. Effectiveness =Availability x maintainability x capability. One helpful tool for easting life cycle cost , LCC, calculation involving probabilities is the effectiveness equation which gives a figure of merit in judging the chances of producing the intended lts. It measures chances of producing intended results. The effectiveness equation is described in several different formats. The issue is finding a system effectiveness value, which give the lowest long-term cost of ownership with trade –off conditions.

System Effectiveness= Efffectiveness/LCC 6

Weibull Reliability Models

The death of most equipment must be analyzed from small samples, using a very practical

Reliability technique of weibull analysis for each failure model[3]

In many cases, a simple technique of MBTF or MTTF is frequently used as percussion for reliability of equipment considering mixtures of failure modes that occur. Failure data and repair time data software for use in reliability calculations are available[8]

Mechanical integrity problems often involves few failures and large quantity of potential future failures. The questions are: when will these mechanical integrity be lost as the next failure occurs, or will the equipment survive with no/few failures until the next scheduled turn around? A factual dataset with few failures is used to illustrate how weibull analysis can forecast the risk of failures based on small dataset[1].The usual dataset includes information in the form of censored data. Good use of engineering judgment and data are used with weibull analysis estimates of failure mode characterized by a slope β to produce a weibull distribution relating age and probability of failure, to make the datasets understandable and practical. Confident intervals can be established and actual history of the plant or similar equipment can be obtained to get a longer population for more realistic failure data. The chance of failure concept is based on using the present data in form of MBTF or its inverse , the failure rate λ .

For the purpose of this study, the weibull analysis of the data helps answer such as what is the availability of the process? What is the reliability of the process? How predictable is the process?[9].

The parameters η, β can be obtained graphically, using special graph paper as in Figure 1.

Reliability graph can be used to determine the optimum maintenance period for any equipment. The availability of the equipment can be increased by predicting failures. This is based on actual shutdown, hence ,repair or replacement of equipment to minimize downtime.

Procedures : The first step is to obtain the equipment failures and shutdown records, with this,, a reliability curve is drawn to obtain the MDT1 for failures and MDT2 for scheduled repairs or replacement. Hence from the above is determined whether this is an optimum time interval between equipment shutdowns.

1 From equipment history records, TBF is tabulated, making sure not to include scheduled shutdowns.

2 The TBF is listed from the shortest to the longest failure intervals and numbered in ascending order of magnitude, from 1 as the shortest, ie n=1,2,3……….N, where N is the total number of failure intervals.

3 Then the probability of obtaining a time between failure greater than each of the failure intervals can be tabulated as follows:

$$R(t) = [\{N - n) + 1] / N + 1]. \quad (7)$$

4 The probability of failure at t hours or less is F(t) and is calculated using the equation:

$$F(t) = 1 - R(t) \quad (8)$$

From Figure 1 is plotted R(t) versus TBF. A straight line is drawn so that it virtually fits the plotted points. This is the reliability graph.

6 Where the reliability curve crosses line B on Figure 1, a vertical line is drawn to TBF scale to obtain η, the scale parameter.

7 Starting at A, line A is drawn parallel to the reliability graph. At the intersection of line 2 on ordinate or R(t) scale. A horizontal line 3 is drawn to intersect the auxiliary scale, $\beta, \frac{\mu}{\eta}$ and $\frac{\sigma}{\eta}$.The shape parameter, β, is read directly from the first scale as well as the second scale, which is used to calculate the MTBF and $MBTF = (\frac{\mu}{\eta})^{\eta}$

8 The calculated MBTF is compared with the arithmetic mean x of the TBF where there is much , much disparity of the two adjustment of the reliability graph until the differences is less than 20%.

9 The equation for the adjustment of reliability graph is the reliability function of the equipment,

ie $R(t) = \exp - (t/\eta)^{\beta}$

9

When equipment items are integrated into a plant system with a given installed capacity, Ui, there individual availabilities will determine the probability that the system at that capacity. This is known as systems effectiveness factor, σ and the product σ Ui is known as effective capacity, Ue, of the system ie

Ue= σ Ui

10

In all repair or replacement model to be considered, there are two mean downtimes;MDT1 and MDT2 , which is as a result of failure and MDT2 , which is as a result of scheduled downtime.

If the equipment is expected to have N(t) failures and N(t) scheduled repairs or replacement over a long period of time, t, then the rate of downtime RDT, may be expressed as:

$$RDT = \lim \frac{DT(t)}{t} = \lim [\frac{MDT1(N(F)}{t}] + \frac{MDT2N(S)}{t} \quad (11)$$

Where $t \to \sigma =$ total downtime in time t=MDT1,N(F)=MDT2N(S). then that which minimizes the objective function= $\frac{DT(t)}{t} \quad t \to \sigma$.

To define the optimum maintenance policy, the failure mechanism of the equipment is modeled as a system of components. Knowing the TBF caused by all component items, it is then possible to model the reliability of the equipment items using the weibull distribution graph. The expansion for the reliability function $R(t) = \exp - (t/\eta)^{\beta}$. The parameters η, β are obtained graphically using the weibull graph paper s. From the graph, could be obtained MTBF and standard deviation σ, of TBF of the reliability model.

The reliability, R(t) of obtaining TBF greater than each recorded TBF,

$$R(t) = \exp(-\frac{t}{\eta})[\{N - n) + 1] / N + 1] = 1 - F(t). \quad (12)$$

Where N is the total number of TBF’S observed, R(t)=1-F(t) , which is a complement of F(t), the unreliability. To find when equipment is due for overhaul, a relationship between the coefficient of variation of the failure distribution, $\frac{\sigma}{MTBF}$, and the downtime ratio MDT2/MDT1(MDT2<MDT1).

If (i) $\frac{\sigma}{MTBF} \geq$ 1-MDT2/MDT1, T0= ∞ (infinity) 13

(ii) $\frac{\sigma}{MTBF}$ <1-MT2/MDT1, To is finite and must be calculated. 14

From the above criteria, two basic maintenance policies are clearly defined. The first is to repair or replace components at a failure, and the second , the optimal policy is repair or replace components at time T, such that DT(To) is minimum, or at failure if it occurs. Figure 2 can be used to plot the points by the pair β , MDT2/MDT1.If the points lie below the curve, the optimal policy is to repair or replace components only at failure, and if it lies above the curve, the optimal policy is to overhaul at To

The optimal overhaul To is given by:

$$r(t)\int_{o}^{t} R(t)dtF(t) = MDT2/MDT1MDT2$$

15

Figure 3 is a development of equation 13 for normal underlying failure distribution. This replacement model is applicable to equipment with a wear out failure mechanism ie equipment items for which the conditional probability of failure given to time, t, is increasingly with t. The conditional probability is called the instantaneous failure rate . Hence weibull distribution is convenient for the purpose of this study because of the relationship between β and the instateneous failure rate with respect to time.

Weibull	Behavoiur of (r)
β >1	increasingly
β =1	constant
β <1	decreasing

The weibull distribution is the most widely used failure data analysis use to study variety of fields , practices, etc. It can analyze burn-in(infant mortality), useful life and wear out data. The primary advantage of weibull analysis is the ability to provide seasonality accurate failure analysis and failure forecast, forecast with extremely small data samples and softwares are used in maintenance planning, development cost effective replacement strategies, spare parts forecasting and warranting analysis. The weibull failure analysis in software can be useful in reliability predictions.

The [2] process reliability wizard technical is a method for identifying problems which have significant opportunities for improvements. The Relex failure data analysis calculates the total reliability losses and efficient/ utilization losses. Reliability models are needed to find when the end of component life occurs as costly replacement follow death of the component. Details of reliability models go into the sustaining costs..

Every piece of equipment is comprised components. Each component has an inherent reliability. Inherent reliability is deterred downward as measured by age to failure, grade of installation and how the equipment is used. Grade is a rank indication of degree of refinement features or capabilities for installation and operation. The grade of equipment installation/operation practices and thus the cost in the acquisition tree are precursors of failures costs covered in sustaining costs[2].

Very high grade installations and very high grade practices foe operation of the equipment demonstrates long age to failure and improve inherent equipment life. However, low grade installation and low grade operations destroy inherent life of equipment. Thus, the effect of practices on inherent life must be obtained by surveys from experts in the field, although may not be the most desired method form acquiring data , but it si most practical considering time and cost.

Data Acquisition

As reliability analysis tools become capable, the availability of accurate and timely data for analysis becomes the limiting factor in the ability to perform effective reliability analysis . Because accurate and timely maintenance and operation information is central to reliability analysis, it is not surprising that reliability engineers tend to champion the development integrated system that provide efficient access to comprehensive and accurate maintenance , operation reliability data. One approach to implement and gain acceptance for a system that meets reliability analysis and other requirements is to build the necessary data capture mechanisms into the organization’s reliability department. We need reliability details to find when thing die. Failure data and repair data can be converted into statistical format using Win Smith Weibull software for use in reliability calculations [10]

Much data needed in the analysis comes from operating and maintenance records which show times between failure and repair time for failures and repair for scheduled maintenance. These details often associated with the field of reliability and maintainability with direct relationship with finding low life cycle costs[11] Proper analysis with the dats can improve maintenance operations.

Additionally, the process provides data for reliability analysis and time- value for detailed life data analysis. However, the effect require to implement such a system is likely to be a complex process that requires the cooperation of multiple disciplines/department within the organization. In order to obtain support for the system, it is important to demonstrate that the system provide tangible benefits to management participating departments and to the entire organization.

Some considerations are given to the design and development of process/system that will maximize efficiency for the affected departments and simultaneously capture/manage valuable reliability information for maintenance. Although the issue of reporting and problem resolution activities occur in most maintenance organizations, the responsibility for problem identification and correction and the valuable reliability information may not be identified and available from analysis. In most cases, the problem resolution process generates the sufficient data at different stages of maintenance of plants life cycle of effective reliability analysis. The changes is to capture and use the information generated from these process by determining how best to store validate, correlate, organize, manage and employ the valuable resource.

A well structured failure recording analysis and cause will simultaneously facilitate the capture and management timely, accurate maintenance reliability data in a comprehensive and systematic way..These process are known as failure reporting analysis and corrective action(FRACA/FRACAS) process systems. The reported failure are reviewed on regular basis. The failure is fully defined , contained corrected and adequate measures taken to present future reoccurrence. Such measures may include:

(i) determine the mode the effect of failure at all appropriate levels(eg. Component, system, etc)

(ii) device and implement and approach the condition and prevent further immediate/ future occurrence.

(iii) reliability data for growth analysis and time to failure for detailed life data analysis.

Computer technology can play a key role in efforts to establish and effective failure reporting cause and effect. The use of computer will make the system be directly related to ease of use and breath of scope , and flexibility as well as easy accessibility for all uses.

Downtime logs can be available source of life data for reliability, maintainability and availability analyses. The reliability analysis data is obtained from information got from the equipment downtime logs must be constructed into a variety of formats and the type of data in the logs determines the process that must be used to convert the log to life data(ie data can be used for reliability analysis). A typical equipment downtime log will contain the dates and times when the events occurred, the date and times when the system was restored to operation and an indication of the component that was responsible for each event. The ‘event’’ can represent systems failures as well as other events of interest, such as user interventions or planned maintenance activities. Some components may continue to accumulate age while the system is down due to the failure of other component, whereas others may accumulate age when the system is operating. The characteristics of the component must be taken into account when determining the time to failure.

Downtime log contains the following information:

(i) the date and time when the system failed;

(ii) the date and time the system was repaired and restored to operation

(iii) the component responsible for the failure; and

(iv) an indicator of whether the responsible component continues to age when the system is down die to failure of another component

Often people feel they lack data when in fact, data is all around them in various degree of usefulness[12] Often data an other important information are acquired haphazardly and annotated poorly. The engineering field of reliability offers many guidelines for how data should be acquired, annotated and used for analysis. Human profits from errors and experiences of various culture in prolonging life by sharing data[13]

In the industrialized world, organization benefit from the experiences of others, they compare failure rates with competitors and other data-bases for quantifying progress toward resolving problems with organization. Failure databases will be required within plants within divisions and within organizations. Keep local data in weibull databases, strategy for industry with communication data base . Databases provide details for life cycle costing by end users to make better decisions about grades of competitive advantages, share data in exponential form (arithmetic) **[13].** Vendors need plants failure data to understand how their products really perform with their competitors. The plant user can acquire more operating hours (and more often) more failures data than vendor / manufacturer will ever acquire during the life time of industrial organizations. Failure data from components and subassemblies cost money to acquire records, analyze and store data. Total failure costs are required for justification of alternative actions and cost effective replacements. The key criterion for understanding plant reliability is the cost of unreliability.

Building a simple Pareto distribution for the cost of unreliability is a real eye-opener for communicating to the organization the needed for improvements to reduce failures

Optimizing reliability starts on 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 in corrective actions.

Hence, reliability optimization process starts simply by collecting age-to failure data and costs associated with failures. Share failure data with vendors and other similar industries that are successful. Use the data arithmetically, and gradually apply statistics to solve problems in the plant.

Validation of the model Using Reliability Graph

In order to arrive at a conclusion of the validity of the mathematical model for failure and overhaul intervals, data were collected from operation and maintenance log sheets of Afam IV power station the following historical failure data were taken from the lo sheet.

Often the missing records of the failures and scheduled overhaul/repair/ replacements were irregular and in some cases missing . GT14 in Afam IV operations and maintenance data were collected. A period of time between 1996 to 2003 was considered.

Table 1: Equipment Downtime Log G14

S/N	System failed		TBF	System repair		Repair
	Date	Time (hours)		Date	Time (hours)	
1	Nov.07-96	18.33	2,000.	Nov.15-96	07.45	Both stator and rotor turbine blade dented
2	Feb. 08 -97	10,10	2,1800	Feb.18-07	10.43	Stamping wire cut
3	Apr. 09-97	06.20	1,300	Feb.18-07	17.48	Warped turbine rotor and stator blade
4	Aug.30-97	14.00	2,470	Sept.10.97	18.16	Turbine rotor blade totally pitted
5	Feb.06-98	08.15	3,000	Feb. 20.97	17.21	Combustion basket damaged
6	Jun. 08-98	13.15	3,050	Jun. 12-98	10.47	No. 1 bearing failure
7	Dec.09-99	06.20	4,420	Dec.14-98	12.00	Compressor rotor first row blade scored
8	Jan. 13-00	15.20	4,510	Jan. 20.00	07.11	No. 2 bearing failure
9	Nov.21-00	07.23	3,700	Nov.25-00	08.22	Combustion chamber cracked
10	May.29-01	13.00	3,700	Jun.4-11	09.59	Turbine rotor and casing damaged
11	Nov. 11-01	19.15	3,794	Nov.19-01	19.00	Pieces of metal in the combustion chamber
12	Mar. 12-02	16.30	5,300	Mar. 20-02	17.00	Cracked compressor rotor blade
13	Aug. 08-02	14.16	4,200	Aug.14-02	15.10	Compressor rotor and stator blade cracked
14	Dec-o9.02	23.30	2,500	Dec.14-02	10.43	No. 2 bearing vibration high
15	Jan. 24.03	12.14	900	Jan. 30-02	22.02	

Plant: Afam thermal power station (Afam IV)
System: Turbine Plant GT14
Period: November 11 1996 – January 24, 2003

Analysis of Failure

From the data collected from Afam iv from turbine GT14 as shown in Tables 1 and 2 using the weibull reliability curve in Figure 1,

$$MTBF = (\frac{\mu}{\eta})^{\eta} = 0.090(3600) = 2864.2$$

$$\sigma = \frac{\sigma}{\eta} = .32(3600) = 1166.4$$

Table 2: GT 14 Failure Analysis

S/N	TBF	F(t)	R(t)	
1	900	0.068	0.932	Observation simple statistics
2	1,500	0.135	0.865	$\bar{x} = \sum_{i=1}^{i=n} \frac{x_i}{n} = 311$
3	2,000	0.175	0.825	$S = \sqrt{\sum (x_i - \bar{x}^2)} / n - 1 = 1{,}092 hours$
4	2,180	0.250	0.750	
5	2,470	0.318	0.682	
6	2,500	0.375	0.625	
7	3,000	0.430	0.582	

8	3,050	0.500	0.500	Theoretical distribution parameters:
9	3,300	0.568	0.432	$\eta = 3{,}600 hours$
10	3,700	0.625	0.375	$\frac{\mu}{\eta} = 0.890$
11	3,750	0.688	0.312	
12	3,794	0.750	0.250	$\beta = 3$
13	4,200	0.832	0.168	
14	4,420	0.875	0.125	$\mu = MBTF = 0.892(3600) = 2854.2 = 0.324(3{,}600) = 1166.4 hours$
15	4,510	0.935	0.065	$Reliability, R(t) = \exp(-t/3{,}600)3.0$

It is assumed that the mean downtime caused by plant failure is three times as long as the the mean downtime caused by scheduled equipment repair or replacement , ie MDT2/MDT1=1/3=0.33

To find whether there is an optimum overhaul, an equation may be determined using Figure 2, from Figure 1 $\beta = 3$,.The intersection of this value MDT2/MDT1 is a point above Figure 3 curve, which confirms that there is an overhaul interval. The policy will be to repair or replace the plant at optimal time interval, To. From the graph , Figure 3 β versus MDT2/MDT1.

$$Z = (To - MBTF)/\sigma = -1.0$$

Therefore

$$To = MBTF + (-1.0/\sigma = 2854.2 + (-1.0)X1166.4 = 2737.56 = 114 days = 4 months$$

Assuming that the plants are operating continuously, they should be overhauled every 114 days or every 4 months. This is not a normal situation with GT 14 turbine series. But one of the reasons could be the poor conditions under which the plant operate, lack of appropriate skills on the part of the maintainers and lack of maintenance policy.

DISCUSSION

The optimal overhaul interval to calculate using the model is however not consistent with moral system requirement. In the above computations, the probability that the plant does not fail before hour 2737,56 hours , the To is about 0.8. If the operating conditions R(To) required is a minmum of 0.9, the To obtained would optimize availability , but would not fulfil reliability requirements. In such circumstances, an overhaul interval must be selected using the reliability model such that R(T0) ≥ 0.90. A convenient figure might be 1, 450 hours or 2 months, which gives the plant 0,93 probability of surviving the overhaul interval. However any decision to increase or decrease the cost of an increasing an increasing downtime will consequently result in reducing the systems effectiveness capacity.

Failure and failure costs in Afam iiv thermal power station are influenced by operating conditions, installation conditions and maintenance condition. Problems should be sorted out and quick solution made. Improvement justifications require knowing:

(i) When things fail;

(ii) How things fail; and

(iii) Conversion of failure into money statements. The maintenance/ operation department should be responsible for defining when failure will occur so that they can be priced out in NPV and this will rely prediction from reliability engineer. The mode of failures will provide information about the causes of failure. The practical obstacles usually encountered in the study are those associated with obtaining accurate and adequate shutdown reports of systems. However, it is important to develop sound maintenance policies and to measure their effectiveness using the weibull reliability analysis.

CONCLUSION

This paper presented the concept as well as the mathematical models and procedures to derive optimized solutions to overhaul intervals to enhance reliability and availability in Afam thermal power station using the weibull analysis. In order to prepare the data for reliability and analysis, the information in the plant downtime logs were converted into time-to-failure and time-to-repair. For power stations, downtime logs can be a valuable source of data for reliability, maintainability and availability. Functional failures have direct adverse effects on operating capability. For each functional effect, the next step is to identify any possible causes that would result in the occurrence of that effect. Once the functions, failures, effects and causes have been identified for each component/plant and each functional failure categorized , the next step is to determine which maintenance tasks applicable and effective to detect and or prevent about the severity of failure. The power station needs high percentage of availability (uptime), reliability (free from failure) predictable failures (low scatter in failures) and problem priorities identification, using Pareto dissolution. The expected reliability of the power plant should be based on the operating experiences of similar unit, the specific performance requirements and the cost constraints of the plant should be taken into consideration also. The availability goal can be converted into reliability and maintainability requirements in terms of acceptable failure rates.

REFERENCES

1. Abernethy, R.B. (2000) , The new Weibull Handbool, 4th e. Dr. R.B Abernethy, North Palm

2. Moubray, J. (1997): Reliability Centered Maintenance, 2nd ed Butterworth-Heinemann, Oxford
3. Fulton, R.W,(1996) ‘Condition, the way forward’’ in Rao, B.K.N(Ed), Handbook of
4. Barringer, H.P. (1995) , Download free Monte-Carlo Software; http://www.barringer
5. Barringer, H.P.(1996) , Proceedings, Annual Reliability and Maintainability Symposium, Cumulative Index ‘’PP-cx-29 for LCC, Evans associates, 804 Vickers Avenue, Durhann, NC27701