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Adopting and Implementing Practical Reliability Tools in Nigeria Electric Power Industry

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ABSTRACT: The dynamics of power plant operations and maintenance has changed drastically over the past decades. In the past, generation and supply of power to both the pub lic and industrial sectors was not competitive, partly because most of the businesses of power generation, transmission and distribution were owned and run by government. The event turned out to be no business as the managers of those plants were not faced with stiff competitions. And as such were not on their heels create, seek and apply new technologies in power operations and management. With the dwindling efficiencies, resulting in outages, black out, most countries developed and adopted new business models where the private sector were allowed to fully own and run the business of power generation, transmission and distribution especially with changing expectations of customers' demands for energy; the power sector became more competitive, resulting in the exit of non-performers. Reliability and availability of power plants become a central focus. The successes recorded in global power sector serves as a business model for non performing countries to copy or modify and apply. This forms the theme of this research to show case how the Nigeria electric power industry can key in into this successful model to turn the fortune of the Nigeria electric power industry in a positive direction. This research presents reliability engineering principles that should be adopted by the Nigeria electric power industry in order to optimize plants' operations and deliver the needed posi-watt and not nega-watt to the ever ready consumers. It is believed that if these measures are judiciously applied, the Nigeria electric power industry will make a huge jump and join the global counterparts in electric energy generation and supply of the needed power.

KEYWORDS: Reliability, Tools, Nigeria electric power station, Failure mode, Predictive maintenance, Scheduling.

INTRODUCTION

Reliability engineering discipline for applying scientific know how to a component, assembly, plant or process so that it will perform its intended function without failure, for the required duration when installed and operated correctly in a specified environment. Reliability engineering is concerned with predicting and avoiding failures- thus it is a strategic task. Maintenance engineering is concerned with quickly restoring failures to an operating condition- thus is a tactical task. Reliability technology helps predict failures and the cost of failures [1]**.** Knowledge about times to failure and failure modes are found by reliability technology. Preventing failure cost money. Repairing failures cost money. Engineering is responsible for defining when failures will occur so that they can be priced-out in net present value (NPV) worksheets and this relies on prediction form reliability engineers. Of course, the mode of failure also provides information about severity of the failure. Reliability engineering applies reliability theory to solve engineering problems. This is done by projecting a system's overall reliability and applying engineering methods to assure these goals are achieved. When reliability is allocated among constituent components, successful mission completion can be established for new designs with relative confidence. For existing facilities, sources of unreliability can be identified and traced back to causes-design, operation maintenance, or a combination thereof. Power plants reliability looks at operating periods. These could be: periods between scheduled outages; calendar periods, budget periods; and peak production periods.

Reliability theory is used to assess small production runs, low volumes, single-use components and systems that usually involve specific, one –of- a- kind missions. Reliability assessment and benchmarking can be used on power industry although deregulation focuses everyone on lower production costs. Within generation of electric power industry, reliability assessment has penetrated to a significant figure. Utilities often consider project which consider long-term operational consequences. This provides an opportunity to apply reliability engineering. Reliability is built upon incremental advances in production methods and facilities, standardized redundancy, layout planning, and common design packages[2]. Nigerians use experience and similar designs to project plant reliability. Designers often support low risks. Reliability factors can help and quantify risks as well.

Reliability engineering can measure reliability, relate that to subsystems and components and reveal which individual reliabilities are needed to achieve a given overall reliability. It can project reliability based upon supporting processes, systems, and components [2]. The goal of this is seeking to provide tools for Nigeria electric power industry to improve plant process reliability to support higher unit plant and systems reliability goals. Reliability theory should drive maintenance. But cooperate culture are powerful change ingredients.

PRACTICAL IMPLICATION

Failure of equipment and processes always occur as a national outgrowth from the laws of physics and can change in entropy [1]. Failure of most equipment must be analyzed from small samples using very practical reliability techniques of Weibull analysis [3] for each failure mode. In many cases, a small arithmetic of mean time before failure (MBTF) or mean time to failure (MTTF) is frequently used as a precursor for reliability. Reliability terminates with a failure- ie, unreliability occur. Failures demonstrate evidence of lack of reliability. The concept of functions and failures in modern maintenance management is very important. Measuring the reliability of plants and equipment by quantifying the annual cost of unreliability into business content. Measurement, planning and improvement are things business do, but only when efforts are focused on important problems.

The objective of –a successful PM programme is to prevent or mitigate the consequences that determine the resources that will be used to prevent their occurrences. This leads to conclusion that the consequences of failure have an adverse effect on safety, operations, environment and cost and the need to carry out preventive maintenance (PM) . Hence, the objective is to build on these simple ideas to determine application and effective maintenance, using reliability tools for each identified failure in Nigeria electric power stations. Therefore it is the objective of this paper to:

(i) Make the management have better understanding of plant and equipment criticality and where it is worth deploying improvement efforts and potential benefits;

(ii) Improve procedures for changeovers and set ups, carry out frequent proactive maintenance tasks, better training of operators and maintenance staff, which will lead to reduced costs and better services ; and

(iii) General increase maintenance productivity and everyone involvement.

Higher plant reliability reduces equipment failure costs. Failure decreases production and limit gross profits. Boosting reliability by reducing cost of unreliability improves business performance. Failures in most process industries are measured in process downtime-cutbacks/slowdowns in outputs are also failures. Failures require a clear definition for organization making reliability improvements. Failures are loss of functions, when the function is needed particularly for meeting financial goals

BACKGROUND OF THE PROBLEM

It is often hard to reconcile maintenance problems that have occurred in Nigeria electric power industries to industrial and domestic losses. It does not just make sense and more importantly, cannot be justified. The effect is that poor maintenance, unreliability and unavailability of power plants has often resulted to loss in generation, high cost of generation and maintenance cost and course, customers' dissatisfaction. At the moment, there have been huge sums of hard currencies plunged into maintenance efforts in the power stations and there is no significant improvement in power supply. This may be attributed directly to corruption and technical irregularities. Yet there are ways to improve the reliability and availability of power stations.

According to the annual international competiveness report, there are significant differences in maintenance effectiveness and individual output between various continents and countries. Consultants frequently use 15 percent as maintenance cost gap between field leaders and world average performance. In addition, the average potential for improvement production has been estimated at around 6 -8 percent [4]. Thomas, 2000.Maintenance practiced in Nigeria electric power industry id crisis –oriented. Crisis-the-day-to-day emergency of random events and directive management-is what Nigeria industrial culture seems on a day to day basis..When business is towards crises, crises are inevitable and structural. Hence, lack of predictive events is what provides crises orientation. Since environment is always dynamic. Proactive maintenance –as can be derive from a failure management- based strategy-can manage or remove a great deal of reactive maintenance.

RELIABILITY POLICIES

In the period up to and shortly after the first world war, equipment was generally simple and robust, The way in which it could fail was easily treated since the simplicity aided diagnostics and in some cases equipment failure was an acceptable reason for loss of production. In this environment, maintenance was largely reactive; simple to fix things when fail. However, during the second world war things began to change to change and the availability of manpower declined in industrialized countries. Equipment became more complex, thus replacing the need for manual intervention and reducing manpower requirements. Loss of production through equipment failure also became unacceptable, leading to work on prevention of failure before they occur. Conventional wisdom suggest that as equipment gets older it ‘’wears out’’ and becomes more likely to fail. Using this model, it was believed that failures could be avoided if equipment was maintained before items ‘’wear out’’ and failure occurred, ie planned intervention at the right time would prevent failures, all that had to be determined was the right time. This line of thought yields the insight into the use of principal maintenance performance indicators to this day, ie the ratio of planned to breakdown maintenance. If the likelihood of items failures increases with age, then planned intervention before that occurred, using this model suggests that if we continue to see failures then we have not intervened early enough ,ie we do not yet know the right age. Therefore it will seem appropriate to measure the effectiveness of our strategy by measuring the amount of planned maintenance. Latter discovery of the aircraft industry and airlines revealed that reliability and overhaul frequency of equipment was not necessarily directly related to age and the common beliefs that reliability decline with increasing age was not generally true. In fact:

(i) Scheduled overhauled has little effect on the overall reliability of a complex item unless there is a dominant failure mode.

(ii) There are many items for which there is no effective form of scheduled maintenance.

[5] , show six patherns of failures , A, B, C, D,E and F as shown in Figure 1.

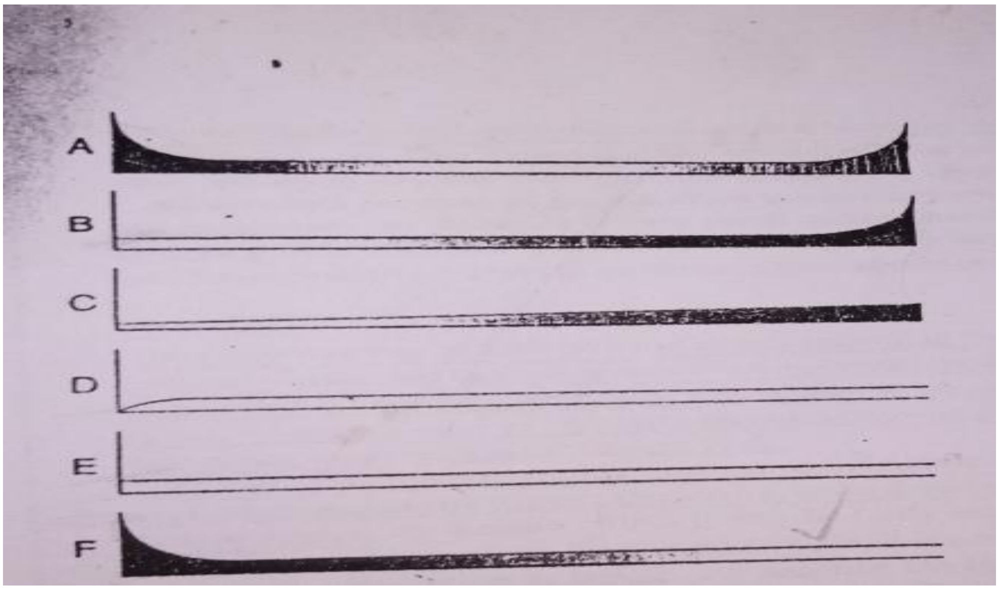

Figure 1: Conditional Probability of Failure against Operating Age for a Wide Variety of Electrical and Mechanical Items [5]

As the results of the various aircraft reliability studies failure curves in Figure 1 were developed. Various studies have since been carried out to relate these curves to other industries [6]. To address these issues, maintenance was faced with four challenges:

(i) to deal effectively with each type of failure process with appropriate maintenance tactics;

(ii) to improve maintenance productivity by moving towards more proactive and planning approach;

(iii) to extend run length between scheduled shutdowns;

(iv) to ensure the active support and cooperation of people from the maintenance, operations and technical functions.

Pathern A is well –known bathtub curve. Pathern B shows constant or slowly increasing conditional probability of failure, then wear- out zone. Pathern C shows slowly increasing conditional probability of failure, but there is no identifiable wear-out age. Pathern shows conditional probability of failure when the item is new, then a rapid increase to a constant level. Pathern E shows a constant conditional probability of failure at all ages (random failure). Pathern F start with infant mortality, dropping to a constant slowly decreasing conditional probability of failure. Studies done on civil aircraft showed that 4% of the items conform to pathern A,2% to B, 5% to C,7% to D 14% to E and fewer than 68% to F. As assets become more complex, pathern E and F become more evident [5].

Failure modes which conform to patterns A or B in Figure 1 become more likely to occur after the end of the useful life.

In general, age related failure patherns apply to items which are very simple ot too complex which suffer from a dominant failure mode. In practice, they are commonly found under conditions of direct wear (most often where equipment comes into direct contact with the product). They are also associated with fatigue, corrosion, oxidation and evaporation[6].

Fatigue affect items-especially metallic items which are subjected to reasonable high-frequency cyclic loads, the rate and extent to which it is protected and the environment in which it is operating. Pathern C shows a steady increase in the probability of failure, but no distinct wear-out zone, unlike A and B which display points at which there is a rapid increase in the conditional probability of failure. The combination of variable stress and erratic response to stress coupled with the increasing complexity means in practice, a high and rising proportion of failure modes conform to the failure patherns D, E and F of Figure 1. The most important characteristics of patherns D, E, and F is that after initial period, there is little or no relationship between reliability and operating age. In the case of such failure modes, age limits do little or nothing to reduce the probability of failure [5]. However, scheduled overhauls can actually increase overall failure rate by introducing infant mortality into otherwise stable systems. From the maintenance management, the main conclusion to be drawn from these failure pathern is that the idea of a wear-out age simply does not apply. The continuing need to prevent certain types of failure, and thr growing inability of classical techniques to do so, are behind the growth of new types of failure management. Foremost among these is the technique known as predictive or condition-based maintenance. Although many failure modes are not age related, most of them give some sort of warning that they are in the process of occurring or are about to occur. If evidence can be found that something is in the final stages of failure, it may be possible to take action to prevent it from failing completely and/or to avoid the consequences.

[5] illustrates what happens in the final stages as shown in Figure 2. It is called P-F curve, because it shows how a failure starts, deteriorates to the point at which it can be detected (point 'P') and then, if it is not detected or corrected, it continues to deteriorate-usually at an accelerating rate-until it reaches the point of functional failure ('F').The point in the failure process at which it is possible to detect whether the failure is occurring or is about to occur is called functional failure ('P'). A practical failure is an identifiable condition which indicates that a functional failure is either or about to occur or in the process of occurring. Examples of potential failures include hot spots showing deterioration of furnace refractoriness, or electrical insulation, vibrations indicating imminent bearing failure, cracks showing metal fatigue, particles in gearbox oil, showing imminent gear failure, excessive wear on bolts, etc. If a potential failure is detected between point P and point F in Figure 2, it may be possible to take action to prevent or avoid the consequences of the functional failure. The tasks designed to detect potential failure are known as 'on-condition tasks'. On condition tasks entail checking for potential failures, so that action can be taken to prevent the functional failure. This is called predictive maintenance because we are trying to predict whether –and possible when-the item is going to fail on the basis of its present behavior) or condition-based maintenance (because the need for corrective or consequence-avoiding action is based on assessment of the condition of the item.

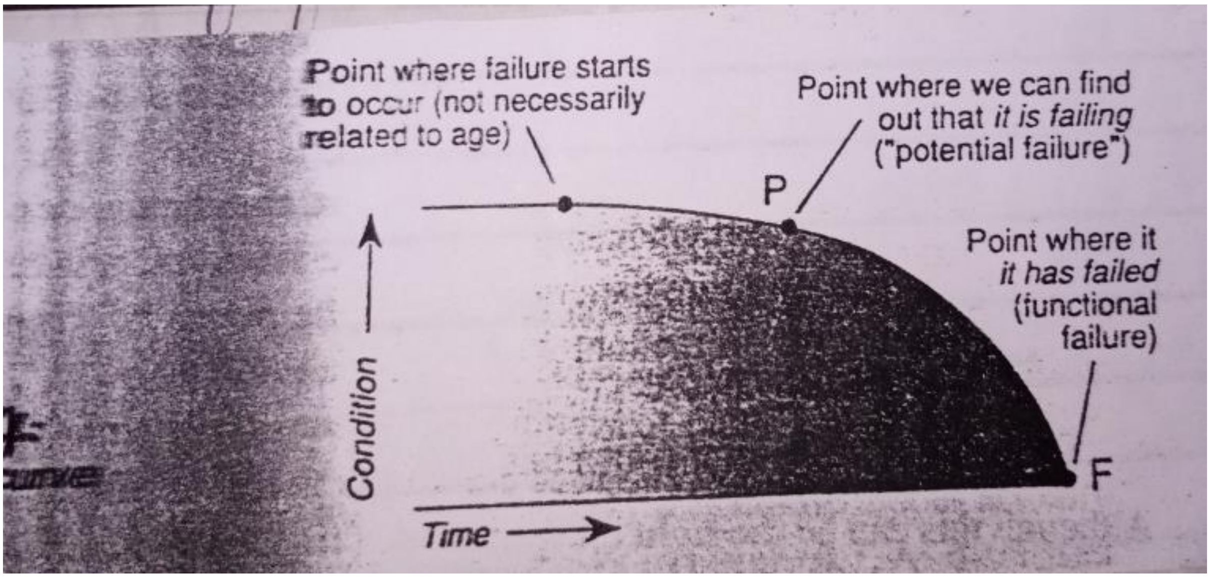

Figure 2: P-F Curves [7]

RELIABILITY TOOLS

Many concepts and practical engineering tools are avoidable for making reliability decisions [8] maintains that knowing about reliability tools is one thing, but using reliability tools in the proper way to reduce the high cost of unreliability is what counts for improving plants and business. Reliability engineering principles provides facts for root cause analysis of problems by organizing failure data for analysis. Reliability tools convert vague probabilistic ideas into nearly deterministic methods associate with crisp decisive actions for rifle short production that help eliminate failures.

A few engineering tools are described below:

(i) accurate failure data is required for making good reliability decisions. [9] says acquiring failure data has basic requirements:

(ii) define an unambiguous time origin;

(iii) definition of failure must be clear and for commercial business, add all elements;
(iv) measure cost consequences for future; and
(v) gain data analysis expertise for using data.

As reliability analysis tools become more capable, the availability of accurate and timely data for analysis becomes the limiting factor in the ability to perform effective reliability analysis. The information required for reliability is often stored in various location within the organization in multiple formats that may be difficult for the analyst to integrate. Accurate and timely product information is central to reliability, it becomes pertinent to develop an

Integrated system that provides efficient access to comprehensive and accurate product quality and reliability data. [10] insists that people in many plants say they lack data when in fact , data is all around them in various degrees of usefulness. Most industrial plants have been acquiring equipment failure data for many years and seldom is the data analyzed in a scientific manner. [9] states that today's task is to 'mine' through piles of existing data in a careful thought out manner so that it can be used for economic advantage. [10] maintains that the key criterion 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 need for optimizing reliability lies in life-cycle costs(LCC) .LCC is useful for trade-off and tracking studies to help find the lowest long-term cost of ownership by considering cost alternatives affecting system effectiveness. The system joins LCC , reliability, availability, maintainability and capability of equipment [11] . Optimising reliability starts in the front end of the design process and works through the LCC using failure data. Optimising the cost of unreliability starts after plants are built and effectively reduces problems built into systems by considering trade –off in corrective actions [8].

RELIABILITY INDICES

Reliability data can be converted into uncomplicated figure-of-merit, performance indices. One simple arithmetic concept is very useful for ''getting a grips'' on reliability by using times between failure derived from the summation of ages to failure divided by the number of failures-this is a simple gross indicator of reliability. Reliability is observed when mean time to failure (MTTF) for non-repairable items or mean time between failure (MTBF) for repairable items is long compared to the mission time. Reciprocals of MTTF and MTBF provide failure rates which are commonly displayed in tables for reliability data[8]. When only a small volume of data is available, the data is best analysed using Weibull analysis techniques to arrive at MBTF and MTTF values. Accuracy of these simple indices are improved when large numbers of data are screened using well known statistical tools.

FAILURE TREE ANALYSIS (FTA)

FTA is useful for merging the probability values for successful and failure with financial results to arrive at the expected monitory result. TAT results are good tools, assessing failure uncertainty in accounting terms[8].

Using decision trees for reliability efforts provides engineers with a business growth opportunity and facts about how money can be spent making reliability improvements.

When an integrated system design is understood, a system block diagram can be built and a mathematical logic reliability calculation is then developed. This is based on the relationships among assembled components and the probability of component failure. Primarily, a design tool, FTA relates overall system performance risk to the supporting component risk which quickly identifies where and how design can be improved to lessen risk. Once FTAs are built, plants can also use them for trouble shooting and sensitivity analysis,

AVAILABILITY-A

This deals with the duration of uptime for operations and is a measure of how often the system is functioning. It is often expressed as (uptime)/(uptime +downtime) with many different variants.

Three frequently used availability terms are explained as follows [12]:

(i) inherent availability (Ai)- as seen by the maintenance personnel(excluding PM, outages, supply delays and administrative delays) is defined as:

$$Ai = MBTF/(MBTF + MTTR) \tag{1}$$

(ii) achieved availability (Aa)- as seen by maintenance department (including both corrective and PM but does not include supply delay and administrative delays, is defined as:

$$Aa = MTBM/(MBFM + MAMT), \tag{2}$$

where MTBM is mean time between corrective and PM actions and MBTM is the mean active maintenance time.

(iii) Operational availability (Ao), as seen by the user, is defined as:

$$Ao = MTBM/(MTBM + MDT) \tag{3}$$

where MDT is mean down.

A few key words describing availability in quantitative terms are :on –line time, stream factor time, lack of down time, and a host of local operating terms including a minimum

Value for operational availability-availability, decreasing downtime and smaller maintenance costs, improved secondary failure costs, and results in better chances for making money because the equipment is free from failures for longer period of time[13].While general calculation of reliability pertains to constant failure rates, detailed calculations of reliability are based on consideration of the failure mode which may be infant mortality(decreasing failure rates with time) or wear-out (increasing failure rates with time). A few keywords describing reliability in quantitative words are: mean time to failure, mean time between / before repairs, mean life of units such sa hours or cycles , failure rates and the maximum number of failures in a specified time interval .

Reliability +unreliability=1 (4)

Higher reliability (few failures) and high maintainability (predictable maintenance times) tend towards high effective systems.als with duration of maintenance outages or how long it takes to achieve (ease and speed) the maintenance actions compared to a datum. The datum includes (all actions necessary for retaining an item in, or restoring an item to ,a specific, good condition) is performed by personnel having specified skill levels, at each prescribed level of maintenance. Maintainability characteristic are usually determined by equipment design which set maintenance procedures and determine the length of repair times. The key figure of merit for maintainability is often the MTTR and a limit for the maximum repair time. Quantitatively it has probabilities and is measured based on the total down time for maintenance including all time for diagnosis, trouble shooting, tear removal/replacement, active repair time, verification, testing that the repair is adequate, delays for logistics movements delays. It is often expressed as:

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

where μ is a constant of maintenance rate, and MTTF , is mean time to repair, MTTP is an arithmetic average of how fast the system is repair and is easier to visualize than the probability value. High availability (high up- time) , high reliability (few failures) and high maintainability (predictable short maintenance times) tend toward highly effective systems if capability is also maintained at a high level.

Effectiveness varies from 0 to 1

Effectiveness=availability*reliability*maintainability*capability(6a)=availability*reliability*performance(maintainability*capability)(6b)=availability*dependability(reliavility*maintainability*capability)(6c) [13]

In other words, the effectiveness equation is the product of : the chance the equipment or system will be available to perform its duty, it will operate for a given time without failure, it is repaired without excessive loss of maintenance time and it can perform its intended production activity according to the standard. Each element of the effectiveness equation is premised on a firm datum which changes with name plate ratings to obtain a true value that lies between 0 and 1. The effectiveness equation is describe in several different formats[14[15][16][17] [11], where each element varies as a probability and the issue is finding a system effectiveness value which gives lowest long term cost of ownership .

System effectiveness= effectiveness/LCC (7)

CAPABILITY

Capability-deals with productive output compared to inherent productive output, which is a measure of how well the production activity is performed to the datum. This index measures the systems capability to perform the intended function on a system basis. Often the term is synonymous with productivity which is the product of efficiency multiplied by utilization. Efficiency measures the productive work output versus the work input. Utilization is the ratio of the time spent on productive efforts to the total time consumed.

Dependability is the product of reliability and maintainability. It measures how long things perform. Pareto distribution and criticality items-working on and correcting the vital few problems that give the largest financial gain are critical to business results. Separate the vital few problems from the trivial many by ranking the financial impacts of problems(not the counts of incidents as is often preferred by engineers) and then work only on initial problems.

Pareto distribution for reliability focuses problem solving effort on key problems offering the greatest potential for improvements using cost of unreliability. However, 10-20% of the items on the list will account for 60-80% of the financial impact[13]. These few items offer the great opportunity for continuous improvement process. The visual format of the ranked cost of unreliability focuses attention on solving the largest problem first and reserves the ‘’nits and lice;; problems to last place because of lack of bottom line financial impact. Pareto lists of all the cost of unreliability costs must include gross margins, when the plant has idle capacity and is ‘’under sold’’. This puts the total cost of unreliability into its proper financial perspective. Communicating improvement programmes to keep management appraisal for their support by using routine progress reports and critical items lists. This requires maintenance and publication of a critical

Item lists. Critical items are failures or potential failures which significantly affect safety, operating successes, pr cause large repair or replacement costs.

Failure mode effect analysis (FMEA) and failure modes effect and criticality analysis (FMECA) is an analysis effects and evaluating reliability by examining tool for evaluating reliability by examining expected failure modes to find the effects of failure on equipment or systems. FMEA is helpful for finding small failures that cascade to large problems. Simple FMEA studies can be enhanced by the use of FMECA status with more details on the chances for costly problem to occur. FMEA and FTA provide systems –perspective risk management tools. Overall failure ‘risk’ for any major plant , equipment, component or integrated system could be assigned a numerical value at the design level. Risk allocation looks at the desired final product and identifies an overall target failure risk. It is broken down to the system and component level, where FMECA identifies the main risk drivers. Design changes (substitutions or re-designs) can address and improve overall mission risk- systematically and on a budget

PLANT RELIABILITY

Monte-Carlo –Statistical distribution give a different value every time data is drawn for solving spread sheet problems because of chance selection. Monte –Carlo simulation techniques are used to join probability distributions and economic data to solve problems of uncertainty using spread sheet technique [13]. Monte- Carlo simulation techniques are random numbers to generate failure and cost data considering the statistical distribution. Monte-Carlo results are similar to real life because the results are used with common spread sheet programmes such as Excel^{TM} and Lotus^{TM} or specialized add-in programmes such as at Risk ^{TM} can add uncertainty to the calculations. Example of Weibull and Monte-Carlo simulations work using the coupling data. Given $\beta = 2.0$ and $\eta = 75$ has, what is a Monte-Carlo age to failure?

Solving the Weibull equation

$$t = \eta * (\ln)1/(1 - CDF)^{(1/\beta)} \quad (8)$$

where CDF is the cumulative distribution function which always varies between 0 to 1. The CDF is convenient because spreadsheets also have a random number function which varies between 0 and 1. Sensitivity analysis allows study key parameters on LCC. The analysis may begin with MTBFs which drives the failure. If all the exponential distribution can be added to obtain an overall failure rates for the system. The key for controlling costs is to avoid the downtime which results in lost margin caused by how the plant is operated. Optimum conditions are rarely achieved in product plants because of the variations in operating conditions and operating styles.

Failure mode effect and criticality analysis (FMECA) is an upgrade of a simple failure mode effect and analysis (FMEA). FMEA is a methodology designed to:

(i) Identify potential failure modes (causes of failures) of equipment before the problems occur.
(ii) Assess the risk associated with those modes; and
(iii) Identify and suggest measures to addressed the most serious concerns

Risk priority number (RPN) method was use in prioritizing issues in different categories of : severity (S), occurrence (O) and detection (D) ,The rating scale used was from 1 to 10. Air compressor, Gas scrubbers, combustion chamber and Turbine were the major sub-systems GT17 used for case study and analyzed as inn Table 1.

Table 1: Data from Afam GT17

S/N	TBF(days)	Probability of failure F(t)	F(t) x100%
1	353	0,1428	14.28
2	454	0.2857	28.57
3	647	0.4285	42.85
4	685	0.571	57.10
5	788	0.714	71.40
6	817	0.857	85.70

MAINTENANCE METHODOLOGY

Maintenance is about preserving the functions of assets. Routine maintenance is about avoiding, reducing or eliminating the consequences of failure.

Planned maintenance- prepared maintenance plans for equipment that requires repetitive maintenance may include standard clearance points, parts, tools, and other resources such as labour and contractors. Planned maintenance is made up of scheduled , on-condition, condition-directed, and some condition-based maintenance.

Preventive Maintenance (PM) Planned scheduled maintenance activity. PM programme is the key to any attempt to improve the maintenance process. It reduces the amount of reactive maintenance process. It reduces the amount of reactive maintenance process to a level that allows other practices in the maintenance process to be effective. However, the Nigeria electric power industry has problems keeping the PM programmed focused.

Maintenance actions are dependent on many factors, such as the failure rate of the machine, the cost associated with downtime, the repair and expected life of the machine. In order to meet these requirements various maintenance strategies have been evolved. Thus , maintenance may be divided into corrective or failure –based maintenance, PM and opportunistic maintenance[18]. Generally speaking, corrective maintenance (CM) is performed to restore an item which has eased to meet an accepted level of operation condition. On the other hand, PM is performed to retain an item at a satisfactory operational condition before failure occurs. PM can be either time base of condition based maintenance means that maintenance is performed at fixed time intervals, whether problem is apparent or not, in order to avoid failure of the item while the system is under operation, disassembled to inspected foe defective parts and repaired accordingly. Time –based maintenance also may create problems where none existed before. [19] cited a 1990 report from electric power research institute (EPRI) ,which states that one-third of the money spent on time –based maintenance in electric industry (which at that year amounted to $60 billion) was wastes. If a machine failure can be taken off line to make only the necessary repairs, a tremendous cost saving can be made .This gave rise to predictive maintenance, also known as condition-based maintenance, which is the carried out in response to a significant determination in a unit's condition or performance as indicate by a change in monitored parameter. Predictive maintenance allows the machine to be taken off line at a predetermined time, which allows production loss to be minimized by scheduling production around the downtime. Here maintenance is done to the normally hidden parts, when exposed due to inspection when the module of the system is stripped to perform CM on PM,

In case of CBM , it is impossible to monitor the condition of every constituent item of the system, as it may not be cost effective, and some of them will be hidden and in accessible for monitoring. CBM is treated as an integral maintenance strategy. CBM is basically applicable to mechanical components whose condition deteriorates with time [20]. This can be done with the help of instrumentation to take regular or continuous measurement of condition parameters in order to determine the physical state of the item on the system without disturbing its normal operation. A few measurement technologies that are used in CBM are: vibration analysis, lubrication analysis; thermography; ultrasonics; accoustics; and high frequency vibration[21]

RCM techniques are now applied to the PM and predictive efforts optimize the programmes. If a particular asset is environmentally sensitive, safety related, or extremely critical to the operation, then the appropriate PM/ predictive maintenance activities is specified. Maintenance approach best suited for an item can be determined using the RCM methodology . RCM provides a structure for determining the maintenance requirements of any physical asset in its operating context, with the primary objective of preserving system function cost effectively[22, [23][6]. Identification of the system functions and functional failures as well as failure modes and effects analysis, are important in RCM.RCM is basically a methodology to balance the resources being used with the required inherent reliability based on the following precepts:

(i) Failure is an unsatisfactory condition and maintenance attempts to prevent such conditions from arising;
(ii) The consequences of failure determine the priority of the maintenance effort;
(iii) Equipment redundancy should be eliminated, where appropriate
(iv) Condition-based maintenance or predictive maintenance tactics are favoured over traditional time-based methods; and
(v) Run-to –failure is acceptable, where warranted.

RCM is an asset –centered methodology with primary focus on making decisions on the of
Of maintenance tasks to be used, TPM on the other hand is a methodology with a very different orientation –it focuses on people and is an integral part of total quality management (TQM). The methodology was developed in Japan's manufacturing industries, initially with an aim to eliminate production losses due to machine breakdowns in Just-in-time (JIT) production systems. TPM redefines the organization of maintenance work by applying the following principles[24].

(i) Cultivate a sense of ownership in the operation by introducing autonomous operator takes responsibility for the primary care of his plant. The tasks involved include clearing, routing inspection, lubrication, adjustments, minor repairs, as well as, cleanliness and tidiness of the operator's work place.
(ii) Optimizing operator's skill and knowledge of his plant to maximize operating effectiveness. The operator is thus mobilized to detect early signs of wear, misalignment, oil leaks, errant chips, or loose parts. He is also involved in making improvement suggestions to eliminate the losses due to breakdowns or sub-optimal performance of the plant.
(iii) Using cross-functional teams consisting of operators, maintainers, engineers and managers to improve people and equipment performance. Establish a schedule of clean-up and PM to extend the plant plant's life and maximize its uptime.

CONCLUSION

Maintenance actions are dependent on many factors, such as failure rate of plants and equipment, the cost associated with downtime, the repair and the expected life of the plant and equipment. In order to meet these requirements various maintenance strategies have evolved. Preventive maintenance plays a major role in today's competitive world, where almost everything depends in the successful operation of plants and equipment. People are becoming aware of the fact that it is essential to maintain the condition of the item in order to achieve greater reliability and availability tools in maintenance strategy with the help of the improved and integrated condition-monitoring techniques, RCM, TPM in Nigeria electric power stations will help to improve maintenance efforts. This article has shown various practical applications of reliability tools in plant maintenance and other best practices in modern maintenance relevant for Nigeria electric power stations. Failures can be prevented and the required reliability level of the systems can be maintained by integrated use of condition-monitoring techniques and by efficient use of reliability tools. The use of reliability tools will enable maintenance engineers in Nigeria electric power stations to decide an optimum maintenance strategy, for each constituent equipment by giving substantive and corroborated diagnostic information with the aid of advance computer technology available today, it will be possible to integrate the necessary tools and techniques on all the plants and equipment into a system in order to get a complete picture of the plants at any given instant of operation. EMECRA of GT17 of Afam power station was shown in this pare as a demonstration of the practicality of the reliability tools.

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