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INTEGRATION OF RELIABILITY, AVAILABILITY, MAINTAINABILITY, AND SUPPORTABILITY (RAMS) IN MAINTENANCE DECISION POLICIES IN AFAM ELECTRIC POWER STATION IN RIVERS STATE NIGERIA

Oti Robinson Chibu

Research Scholar, Department of Electrical and Electronic Engineering, Rivers State University, Nkpolu Oroworukwo Port Harcourt, Nigeria

ABSTRACT

The objective of every electrical power producer is to meet its customers' supply demands at a reasonable cost. Therefore plants and equipment in these stations must have availability, reliability and predictability ***life-cycle cost*** *(LCC). Due to maintenance problems and poor supportive systems, Nigeria electric power generating stations are not able to meet their customers' requirements; these are the major causes of customers' dissatisfaction in power supply requirements. Often it is traced back to expected failures leading to unexpected losses and costs. However, with proper consideration of* ***reliability, availability, maintainability, and supportability*** *(RAMS) in maintenance systems decision policies, the number of failures can be reduced and their consequences minimized. Based on experiences of the industrialized countries, an approach for integration of RAMS and risks analysis in maintenance system can be developed as a guide for appropriate maintenance policies. This paper discusses the importance of* ***failure mode effect analysis*** *(FMEA). Failure mode effect criticality analysis (FMECA), LCC analysis, use of feedback information, supportive systems risk analysis, with the integration of various information sources to facilitate easy RAMS implementation in maintenance decision policies. This approach is suggested for implementation in Afam electric power station for the maintenance decision policies as a management control to reduce risk and uncontain costs.*

KEYWORDS: *RAMS, Management, Risk Analysis, Maintenance of AFAM Electric Power, Nigeria*

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INTRODUCTION

The integration of reliability, availability, maintainability, and supportability (RAMS) with risk analysis will enable an organization to optimize resources in their planned maintenance (PM) activities and processes. Also, this will bring about a framework that will reveal inefficiencies in the maintenance system and will identity the need for updating maintenance time standards and material requirement planning activities. This paper emphasizes the importance of RAMS and risks analysis for failure-free operations of electric power plants. A need for effective and efficient control of information flow and the work processes has been identified as critical to the successful integration of RAMS and risk analysis in the maintenance processes. This paper demonstrates the application of RAMS tools and methods necessary for successful improvements of the maintenance systems in Afam electric power generating station in Rivers State Nigeria.

With the current level of advancement, both in engineering and business management disciplines of the industry coupled with tighter regulatory polices, the performance in maintenance management has gained consideration momentum, particularly in high risk and capital-intensive industries such as power generating stations. The electric power industry in particular, is keen on the assurance of proper control of production through proactive maintenance of assets.

Today's economic and competitive environment requires that industry sustain full production capabilities and minimize the cost of capital investment from the traditional reactive maintenance mode to proactive maintenance and management philosophies. Maintenance processes that fully address the technical concerns of maintenance must be adopted and the process must realize the value of integration of engineering planning and maintenance that requires a shift in maintenance paradyme. Integration of RAMS with risk analysis is such a process. Some **independent power producers** (IPPs) have replaced traditional maintenance staff and annual-unit outrages with flexibility scheduled overhauls at the lower cost. The management of Afam electric power plant dose not see investment in training as high reword in maintenance policy, but rather convey an implicit message that says that performing the job right the first time has little or no organizational value. There should be new means that more work practices, which means that more work performance need to see others methods Maintenance improvement throughout industry in the advanced countries include reliability centered maintenance (RCM) and **total productive maintenance** (TPM) while each represents a good state at defining and advancing the maintenance profession each has intangible aspects that bring total quality maintenance to mind, while the RCM and TPM have their place, tangible techniques will have greater success in Nigeria electric power industry environment. Successful maintenance hinges on bringing fundamental organizational skills together with performance, August (1999) points out that these key processes inherent to any business are exceedingly difficult to learn and perform and are usually developed through experience inside the business.

The modern view of maintenance is that it is all about preserving the functions of physical assets in order words carrying out tasks that serve the central purpose of ensuring that plants and equipment are capable of doing what the user wants them to do when they want them to do so. The modern business world is a rapidly changing environment so the last thing an organization needs if it is to compete in the global marketplace is to get in its own way in which it approaches the business of looking after its income-generating typical assets. The main purpose of this paper is to examine the critical issues such as reliability, availability, maintainability, and supportability (RAMS) etc. which directly affects maintenance system of the Afam electric power industry needs as being practiced by developed countries of the world most physical products and systems wear, tear and deteriorate with age and use. In general, due to cost and technological consideration, it is almost impossible to design a system that as maintenance free (Markeset and Kumar. 2003) in fact maintenance requirement come into consideration mainly due to lack of proper designed reliability and quality for the tasks or functions to be performed other requirements such as human error, statutory requirements, unreliability, quality and failure influence maintenance concept and supportability.

Product support and maintenance needs of systems are more or less decided during the design and manufacturing (Markeset and Kumar, 2001; Blanchard and Fabryky, 1998; Goffin. 1998) often the reasons for product failures can be traced back to design engineers' and management's inability to foresee problems. Furthermore, the strategies adopted by owners/users concerning systems operation and maintenance, also considerately affect maintenance and supportability needsThe early space programmes study failure processes in it man/machine systems. Failure "modes" their effects and processes evolve to the recognition that process, as well as products and systems, fails. Root evaluation categorization and oversight methods such as management oversight risk tree (MORT) along with reliability were developed into the identification and study of failure modes and their effect emphasis shifted from performing repairs the traditional focus of maintenance – to understanding the cause of failure (August 1999), key aspects of the initial findings including; system focus, recognition of complexity as an important attribute in modern equipment; failure classification by modes; assessment of failure effects on the system and numerical and statistical data evaluation of large equipment populations (Augustine, 1999). Theoretical assessment of what maintenance can do and can't do, the completeness of maintenance plans and options for equipment assessment identified were this new approach with the advent of RCM provided a standard, common methodology for assessing, ranking and provides the structural glue that holds together three professions, operation, maintenance, and engineering.

The key RCM points include; strategic mission-oriented thinking. system equipment approach; function understanding, technology assessment; fact-based decision processes; failure analysis; profound process understating, continuous improvement completeness, functional failure focus; risk management, orientation, failure modes identification, classification, standardization and identified general strategies.

Hence, where and how improvement efforts can be identified, using information and simplified analysis. The overall objective will be to meet mission, goals-usually in the form of costs, safety, risk, reliability, availability, maintainability, and supportability (RAMS).

BASIC CONCEPTS AND DEFINITIONS

Reliability

Reliability is the probability of equipment or a process to function without failure, when operated correctly, for a given interval of time, understated condition (Barringer. 2000). Reliability terminates in a failure, and then the business incurs the high cost of unreliability problems for controlling and reducing costs. Enhancing reliability satisfies customers for on-time deliveries through increased equipment availability and by reducing costs and problems from products that fail easily. Reliability in power plants looks at operating periods. These could be period between scheduled outages; calendar periods. Budget periods and peak production periods. Measuring the reliability of plants and equipment by quantifying the annual cost of unreliability incurred by the facility puts reliability into a business failure costs. Failure decreases production and limits gross profits. Failure demonstrates evidence of unreliability with unfavorable cost consequence for business.

Failure in most continuous process industries is measured in process downtime. Cutbacks/ slowdown in output is also a failure. Failures are loss of function when the function is needed particularly for meeting finance goals. Failures require a clear definition for the organization making reliability improvements.

Reliability deals with reducing the frequency of failure over a time interval and is a measure of the probability for failure-free operation during a given interval, i.e. it is a measure of success for a failure-free operation, and it is often expressed as in Eqn. (1)

$$R(T) = \mathrm{Exp}\,(-T/\,MTBF) = \mathrm{EXP}\,(-T/MTBF) \qquad (1)$$

Where:

R is constant failure rate and MTBF is mean time between failures and is easier to understand than probability number. For exponentially distributed failure models. MTBF is a basic figure-of-merit for reliability (and R is the reliability and may be the product of many different reliability terms such as shown in Eqn. (2)

$R = R_{turbine} \times R_{compressor} \times R_{Combustion} \times R_{scrubber}$ (2)

To the operator of a plant, reliability is measured by a long failure-free operation. Long periods of failure-free interruption results in increased productive capability while requiring fewer spare parts and less manpower for maintenance activities, which results in lower costs. To the supplier of a product, reliability is measured by completing a failure-free warranty period under a specified operating condition with few failures during the operating life of the equipment. Improving reliability ushers in the expectation for improving availability, decreasing downtime and smaller maintenance costs, improved secondary failure cost and results in better chances for making money because the equipment is free from failures for longer periods of time.

While general calculations of reliability are related 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), chance failure (constant failure rates with time) or wear-out failure (increasing failure rates with time). A few keywords describing reliability in quantitative words are: mean time to failure, mean time between failures, mean between/before maintenance actions, mean time between/before repairs, mean life of units in counting units such as hours or cycle, failure rates, and the maximum number of failures in a specifically time interval. Reliability plus unreliability equals unity (1) High reliability (few failures) and high maintainability (predictable maintenance times) tend towards effective systems.

Availability

Availability deals with the duration of up-time for operations and is a measure of how often the system is alive and well. It is often expressed as up-time /(up-time + downtimes) with many different variations. Up-time and downtime refer to the capability to perform the task and downtime refers to not being able to perform the task, also availability may be the product of many different terms such as:

$A = A_{hardware}\ A_{software}\ A_{human}\ A_{interfaces}\ A_{progress}$ and similar configuration

Davidson (1998) points out three factors for availability increasing time to failure decreasing downtime due to repairs or scheduled maintenance and accomplishing the above two in a cost-effective manner as availability grows, the capability for making money increases because the equipment is in service a longer period of time.

Ireson (1996) explains three frequently used availability terms as:

- Inherent Availability (which excludes PM outages, supply delays, and administrative delays) is given as:

  Al = MTBF/(MTBF + MTTR)

- Achieved availability (which includes both corrective maintenance (CM) and (PM) but does not include supply delays and administrative delays) is given as

  Aa = MTBM/MTBM+MANT); and

- Operational Availability which is given as:

  $A_o = MTBM/(MTBM+MDT)$

  where

  MTBM = Mean time between corrective and preventive maintenance

MTBF = Mean time between failures

MAMT = Mean active maintenance time

MTTR = Mean time to repair

MDT = Mean down-time

A few keywords describing availability in quantitative words are online time, stream factor time, lack of downtime, and a host of local operating terms including a minimum value for operational availability (Barringer and Webber, 1996). A system must be available (ready for service) and reliable (absence of failures) to produce effective results.

Maintainability

Maintainability deals with duration of outages or how long it takes to achieve (ease and speed) the maintenance actions compared to a datum; the datum includes maintenance (all actions necessary for retaining an item in or restoring an item to a specified good condition) is performed by personnel having specific skill levels, using levels, using prescribed level of maintenance. Maintainability characteristics are usually determined by equipment design which set maintenance procedures and determines the length of repair time. The key figure of merit for maintainability is often the mean time to repair (MTTR) and a limit for maximum repair time qualitatively it refers to the ease with which hardware or software is restored to a functioning state. Quantitatively it has probabilities and is measured based on the total downtime for maintenance including all-time for diagnosis, troubleshooting, tear-down, removal/replacement, active repair is adequate, delays per logistic movements and administrative maintenance delays. It is often expressed (Barringer and Weber, 2000) as

$$M(t) = 1 - \exp(-t/MTTR) = 1 - \exp(ut) \ldots \quad (3)$$

Where

U $\rightarrow$ is constant maintenance rate and MTTR is mean time to repair

MTTR is an arithmetic average of how fast the system is repaired and it is easier to visualize than the probability value. The maintainability issue is to achieve short repair times for keeping availability high so that downtime of productive equipment is minimized for cost control when availability is critical.

Three main items of downtime are controlled are:

- Active repair time (a function of design, training, and skill of the maintenance personnel)
- Logistic time (time lost for supplying the replacement parts; and
- Administrative time (a function of the operational structure of the organization) high available high up-time) high reliability (few failures) and high maintainability (predictable and short maintenance times) tend toward highly effective systems if the capability is also maintained at the high level.

Supportability (support systems)

Strategic initiatives such as multi-skilling, intertrade flexibility outstanding. RCM, TPM, redesign of work processes and structures often needed in proactive maintenance may fail to deliver the expected benefits. The main season for such failure is that values, management and reward systems that align with these initiatives were not in place when the change programmes were implemented. Effective deployment of information technological in support of maintenance operations is also a critical issue. The supportability includes participation and autonomy, education and training, reward and recognition, performance measurement management information systems etc.

Participation and Autonomy

Employee empowerment is a core concept shared by those in the organization, with the expectation of creating internal commitment in employees. To get an internal commitment, management must involve employees in defining work objectives, specify how to achieve them and setting stretch targets. If employees have little control over their destinies, the organization only gets an external commitment that is akin to contractual compliance. While autonomy should be like the core concept of empowerment, management retains control through information systems, processes, and tools. Thus, employee participation and autonomy must be in place for empowerment to take root.

Education and Training

Empowerment will have no meaning if employees fail to get the right tools, training on their use and support in the implementation. Educational resources, which can include technical and consultation as well as training, must be available and accessible to employees with identified needs. Organizations offer training programmes for their employees and customers. All the employees need to be trained in respect to design for maintenance issues and utilization of new RAMS tools and methods, as well as risk analysis and evaluation. However, training should not be limited to the transfer of technical skills and knowledge needed for optimal task performance. It should also cover generic matters like business imperative peculiar to the organization, (what determines the value of its product and services to customers), problem-solving techniques, team dynamics, and facilitation skills. The additional training for managers addresses issues such as the new roles (leadership, communication, coach resource providers) they perform in the change programmes and the new management bahaviors that will align efforts and engender commitment towards organizational goals (Tsang, 2002).

Reward and Recognition

If an organization stresses teamwork, the remuneration structure should promote teamwork rather than undermine it. Meimoun (1995) studying Fel-pro and steel case on two best practice organizations identifies the following critical success factors for a reward and recognition system that encourages teamwork.

- Top management commitment to teamwork and the concept of team-based rewards and recognition.
- Management is available and visible
- Employees are regarded as the organizations most valuable assets
- Employees value empowerment and involvement as a form of reward and recognition.
- The organization relies on structures processes policies and documentation
- A strong network is in place for vertical horizontal, diagonal, intra-team and inter-team communication.
- A performance measurement is in place and employees participate in training.

Offering employees the "right" rewards alone is unlikely to produce sustained empowerment. The power of such methods wears off with use, creating a dependency to maintain commitment. Just, involvement and autonomy are the lasting ingredients that drive human energy and activate the human mind.

Performance Measurement

Performance is measured with reference to clearly defined objectives. Campbell (1996), classifies maintenance performance indicators as measures of:

- Equipment performance such as availability, reliability, and equipment overall effectiveness.
- Cost performance such as labor and costs of maintenance and
- Processes performance, such as the ratio of planned and unplanned work, schedule compliance.

Typically, these performance indicators are tracked because of the following reasons (Tsang 2002).

- These indicators have been used by the organization in the past.
- Some of them are used for benchmarking with other organizations and
- Some of them are mandated by regulations on the corporate office.

Performance indicators should highlight a "soft spot" in an organization, then enable further analysis to find the problem that is causing the low indicator, and then ultimately point to a solution to the problem performance indicators are valuable tools in highlighting areas that are potential processes to be benchmarked.

Simons (1995) points out that three diagnostic measures that determine whether the various aspect of maintenance operations remain in control or compare favourably with counterparts elsewhere. Thus they are used largely to support operational control and benchmarking purposes. Continuing, his introspective perspectives, these generic measures are inappropriate to provide a holistic assessment of maintenances performance. Furthermore, it does not provide information for predicting the unit's ability to create future value needed to support the business success of the organization (Tsang 2002) points out that achieving this purpose performance measures must be tracked. These are known as strategic measures (Tsang, 1998) presents a process for managing maintenance performance from the strategic perspective.

Kaplan and Norton (1996), provide a process called the balanced scorecard (BSC) that presents a strategic performance measure around four perspectives financial, customer, internal processes and learning and growth. By using the BSC the strategic is translated into something more tangible and actionable-long-run (strategic) objectives, the related performance measures and their targets, and action plan. The BSC is a powerful communication tool for providing a sharp focus on factors that are important to maintenance in making a contribution to the business success of the company it enables assessment of unit performance and guards against sub-optimization because all the key measures that collectively determine the total of maintenance are monitored (Tsang, 2002). Tsang and Brown (1998) give a report on an electric utility experience of introducing BSC to measure the total performance of the maintenance function. As deregulation progresses, generation reliability and cost per net MWH take on greater importance, the need for risk analysis and RAMS will increase. Measures need to focus on risk and economic importance. To quantify risks, consider such things as unit forced outage data; equipment emergency work orders: overtime; special part claims and audits; regulatory information or audit findings and industry experience.

Information System

Managers of power plant facilities formulate strategies, make decisions, and monitor progress against plans by collecting, retrieving and analyzing data. Management information systems should allow a seamless flow of information through this organization to support these managerial tasks. However, managers often fine that their exiting information system does not communicate with each other and their operating practices are inconsistent. This is because these so-called legacy systems were developed at different times to serve their dedicated purposes with little, if any, consideration for integration with other systems. The emergence of Enterprise Systems (ES) - software packages with fully integrated modules for the major processes in the entire organization-often the promise to integrate all the information flows in the organization with the following benefits.

- Replacing a large number of the legacy systems with an integrated one produces significant cost saving. It eliminates the expensive tasks of maintaining redundant data, transferring data between incompatible systems, and updating and debugging obsolete software code; and
- Managers can make informed decisions when data on multiple aspects of operations are readily available for analysis. If the work order control system is incompatible with the inventory-control and purchasing systems, then maintenance jobs cannot be done efficiently when the critical spares are not available. Fragmentation of information is a cause of incoherent decisions. The required ES modules should have the following features include facilities for maintaining records of equipment history, support for PM, work-order control, inventory control and purchasing. Through integration with the other shop-floor data collection, knowledge-base diagnostics, etc, real-time decision-support information can be retrieved by managers using user-friendly interfaces.

The Following Requirements are Necessary for the Software Modules

- Functions to support modeling of lifetime distributions, inspections or PM schedules, or equipment replacement decisions.
- Support for documentation of **failure mode effect and criticality analysis** (FMECA);
- Performance results in a specified format if BSC is implemented, the system should be able to support it. Hence, the logic should follow the logic of the process-strategic objectives are linked to their performance measures which in turn, have their respective targets; the top-level BSC is deployed to lower level ones in a cascading manner. This should be done through a **graphical user interface** (GUI). The system should allow the user to get through high-level measures to reveal further details provided by the lower level measures they summaries. The information level should be accessible in real time to all employees who play a direct role in affecting the performance traced.
- With strategic partners in its logistics system, there are huge benefits in establishing direct electronic links with their software systems. If the inventory control, purchasing, and account payable modules can communicate seamlessly with their counterparts to the supplier, then provisioning of spares can be managed efficiently with minimal human intervention and transactions can be processed with low human error rates.

Risk Analysis

IEC 60300-3-9 (1995) standard defines risk as the combination of the frequency, or probability of occurrence and the consequence of a specified hazardous event. Nowlan and Heap (1978); Moubray, (1997) maintain that in order to identify risks in terms of where these are located in a system and how serious they are. Risk analysis can provide guidance as to where maintenance actions should be directed. For example, maintenance methods, RCM use function analysis in combination with risk analysis in prioritizing maintenance actions. Backlund, 1999, Townsend, (1998) point out that there are many different opinions regarding what risk analysis implies and how it should be used. Backlund and Hannu (2002) maintain that since risk analysis is the identification of risk sources in terms of their loction and magnitude, it can form the basis for maintenance decision making. In the risk analysis, the total asset is further scrutinized by identifying the largest risk resources in each sub-system. The percentage of each risk sources that contributes to the risk of each sub-system is computed. For example, in a gas turbine, the percentage of total estimated asset risk in sub-systems such as scrubbers, turbine, compressor, filters, and combustors ete can be analyzed. It is pertinent to have an idea or be conversant with the plant and sub-systems to be analyzed.

A preliminary hazard analysis and systematic initial consequences are necessary. The operators and maintainers who are experienced with the system must be thought risk analysis. Operators and maintenance staff should have excellent risk perception. Industry experience around plants for many years, knowing how they are run, and what fails, helps interpret risk patterns. Pre-planned, on-line maintenance periods can usually be planned so that there’s less risk of the unit outage.

In the absence of a “near-miss” programme, one method of identifying system risk level performance is to track two measures that correlate system risk-system equipment emergency are work orders (WOs), and overtime. These will indicate how unplanned maintenance influence system performance. Cost measures including total man-hours worked, total costs, and how these are allocated between and among various work categories need to be following at the system level. This should be displaced in Pareto fashion.

RAMS Tools

Central in the efforts of integrating RAMS with the risk analysis in the maintenance system is the computer-based FMECA methodology. FMECA is a powerful analysis method involving two elements of risk; namely, failure frequency and consequences. FMECA analysis concentrates on the identification of the events and frequency resulting in failures and analyzing their effects on the components and systems. Information about how system, subsystem or component can fail and their respective weaknesses originate from experience, feedback from operators, maintainers, the vendors, testing, spare part and warranty data, project review reports etc Canter (1997) points out that if a failure mode is identified, its risk is predicted by estimation of failure frequency, consequence, and detectability to make it possible to avoid the event, or at least to reduce the severity of the consequences. The analysis and design-out of the failure cause or respective action has to be done in product design.

The intention of the RAMS tool is to formalize and standardize maintenance processes with respect to RAMS, to meets customers demand in plant generation availability and reliability. Although industrialized countries have been using FMECA analysis, this tool is not yet considered in any industry in Nigeria. The FMECA analysis with risk analysis provides a basis for decision- making in PM, spare parts and maintenance tools, documentation (including procedures, routines and checklists for installation, failure diagnosis, and life cycle cost (LCC) predictions. The analysis also serves as the basis for operators and maintainers training and feedbacks to the vendors. The main purpose is to improve plant and equipment performance, reliability, availability, predictability, reduce costs, increases product-related performance and customer satisfaction.

Risk Management

Ultimately, improved performance comes from better maintenance selection, timing, and performance. RCM helps the selection timing and provides tools to raise awareness. As maintenance programmes improve, two things become evident. Crisis decrease, but maintenance costs run higher. As crisis decrease, overtime, low productivity work, material parts expenses, and service expenses fall. As more megawatts are produced, unit costs drop. This decrease in unit production cost is due to increased availability and reliability.

Risk assessment consists of three elements. The first question to be asked is what could happen if the event under consideration did occur? The second is how likely it is for the event to occur at all? The answers to these two questions will provide a measure of the degree of risk containment. The third and often the most contentious question is whether this risk is tolerable.

When more people have access to information that supports performing maintenance, better decision making will result in more dialogue and development of trust between and among workers, maintenance schedules, and analysis, is necessary. The adoption of RCM-based PM format takes the questing out of all time-based (maintenance (TBM)/condition based maintenance based (CDM) task for a turbine, many inspection tasks need to be performed based on time and risk. Some include instruments, penetration welderment inspection, failed thermo couple replacement, failed pressure ensuring line replacement, calibration, and control connector inspections.

Stages: blade dispose removal, LP stages tie wrap inspections, blade root tip crack inspection, bearing dimensional checks, steam cut checks (across gaskets, along with the spit casings, at penetrations), bolt crack inspection, and rotor crack inspection.

Overhaul activity requires turbine stage disassembly. Effective overhauls require using both time-based and condition-based maintenance risk management. For example, the rotor bore crack inspection-rotor-bore cracks are low probability event, but ones with great potential consequences. The utility, risk profile for such an event and cost factors are major generation risk factors manufacturers recommend performing inspections on every overhaul. This adjustment provides risk management, but also substantially reduces overhaul costs. Overhaul task can be time-based or on condition. For example, performance efficiency, loading behavior, and main-bearing vibration trends are on-condition indications. Time-based age mechanism includes blade root tie crack, tip wrap tracks and control value deposits. An instrument can convert time-based tasks to on-condition tasks. Blade deposit can be monitored by careful stage efficiency tests. That necessitates instrumentation maintenance such as calibration (August 1999). Overhaul timing can be improved using a combination of known aging performance history since last overhauled, and condition monitoring as an ongoing risk control practice.

August (1999) maintains that the following are necessary on-condition monitoring

- Bearing temperature (thermocouple replacement)
- Bearing vibration (bearing inspection and rework);

- Performance (specific problem identification and correction-like blade deposits and erosion-especially stage performance, load capability and response.
- Control value position trends (value stem and seat rework,
- Value stroke tests (value packing and operators);
- Turbine protection tests (protective devices rework), and
- Conditional overhaul, specifically correct equipment failure, its cause, and any secondary failure

Tools, Methods, and Models in RAMS and Risk Analysis

There are many tools and methods available to assess RAMS, LCC and to apply risk analysis during maintenance function planning. RAMS tools like FMECA, fault tree analysis (FTA), and event tree (ETA) are useful in the dimensioning plant and equipment maintenance policies and maintenance supportability as demanded for more uptime, low maintenance cost, more effective and efficient work processes are more important than even to examine factors that affect plant and equipment performance, maintenance and supportability. The computerized tool is now starting to be used actively in the maintenance system. The Relia-soft xfmea software has been designed to automate and facilitate the FMEA? FMECA process and improve flexible data management and reporting capabilities. FMEA and FMECA are methodologies designed to identify potential failure modes for assessing the risk associated with those failure modes and to identify and carry out measures to address the most serious concerns.

There is a great variety with industry as to the specific implementation details for individuals FMEA/FMECA analyses. A number of standards and guidelines have been developed to set the requirements for the analysis and each organization may have a unique approach to the analysis. Some common-FMEA/FMECA-guidelines/standards include the U.S. Department of Defence's MI-LSTD-1629A (1998), SAE international J 1739 (2001) and Aerospace Recommend practices ARP5580 (2001) documents (for automobile and non-automobile applications, respectively) and the Automotive Industry Action Groups (AIAG) FMEA-3.

In addition, some practitioners distinguish various types of FMEA/FMECA analysis based on the item or process that is analyzed, the stage in the manufacturing/ development process when the analysis is performed on the hardware or the functions that the item is expected to perform. Some commonly acknowledged FMEA types include, but not limited to, design FMEA (DFMEA), Process FMEA (PEMEA), functional MEA (FMEA) and system (SFMEA). Even though there are many different types and standards, most FMEAs FMECAs consist of a common set of procedures. In general, FMEA analysis is conducted by a cross-functional team at various stages of the design, development and manufacturing process and typically consists of the following:

- Item/process: identify the item or process that will be the subject of the analysis including some system, the analysis could be performed at the system, subsystem, component or another level of the system configuration;
- Functions: identify the functions that the item or process is expected to perform
- Failures: identify the known and potential failures that could prevent or degrade the ability of the item/process to perform its designation functions;
- Failure effects: identify the known and potential effects that could result from the occurrence of each failure. It

may be desirable to consider the effects at the item level (local effects) at the next higher level assemble (next higher level effects) and/or at the system level (end effect)

- Failure causes: identify the known and potential causes for each failure;
- Current control: examine the control mechanisms that will be in place to eliminate or mitigate the risk and then follow up on the completion of those recommended actives;
- Prioritize issues: prioritize issues for corrective action according to a consistent standard that has been established by the organization. Risk priority number (PRN) ratings and criticality analysis are common methods of prioritization.
- Other details: depending on the particular situation and on the analysis guidelines adopted by the organization, other details may be considered during the analysis such as the operational mode when the failure occurs on the systems intended mission: and
- Report: generate a report of the analysis in the standard format that has been established by the organization. The report may include block diagrams and/or for process flow diagrams to illustrate the item or process that is the subject of the analysis may be included in a separate table and various plots/ graphs can be included to display statistics on the modes and rankings.

Application of FMEA/FMECA

FMEA techniques are used throughout industry for a variety of applications and the flexible analysis method can be performed at various stages in the product life-cycle FMEA?FMECA analysis can be employed to support design, manufacturing, maintenance policies etc to improve reliability, maintainability, and supportability. For example, RCM procedures incorporate FMEA and a primary component of the analysis (Fig. 1). In addition, the FMEA reporting can be used to provide a centralized location for reliability-related information.

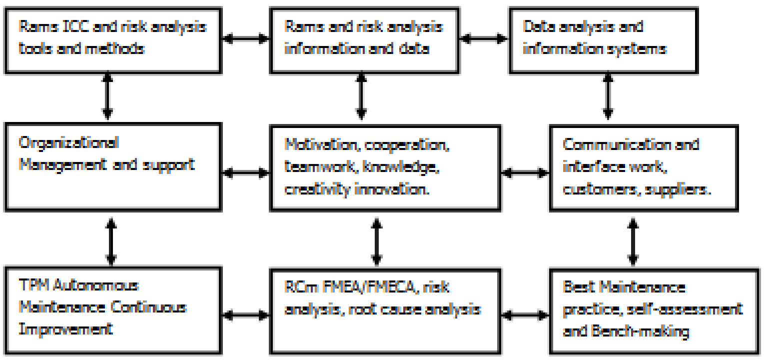

Figure 1: FMEA Techniques Used in A Variety of Applications and the Flexible Analysis Method can be Performed at Various Stages in the Product Life Cycle

CONCLUSIONS AND RECOMMENDATIONS

The Nigerian electric power industry has TBM in its PM programmes and still has high downtime and high maintenance costs in its maintenance efforts. These are no move to adopt the proactive steps currently being employed in the industrialized countries. From studies earlier done on this industry, there is a need to integrate RAMS and risk analysis in its maintenance processes. This could be implemented gradually and phase –wise with feedback to monitor the effect.

By integrating RAMS and risk analysis in the maintenance processes it will help reduce risk, install reliability, availability which are lacking presently in the system. There will be a need for effective and efficient control of information flow and analysis. The organization needs to implement a training programme with the focus on integrating of RAMS and risk analysis in maintenance processes.

The Nigeria electric power industry needs to initiate measures to coordinate RAMS implementation in different sections and departments. It is likely that successful integration of RAMS and risk analysis will provide the organization with a competitive edge and the successful implementation will mainly depend on the organization's ability to create awareness and understanding of the issues involved. The employees need to be trained to use the appropriate tools and methods, and an infrastructural facility needs to be in place to make these tools information resource available when needed. It is important to consider the coordination between work processes, tools, and information services to be able to get an optimal result. Procedures, routines, and checklist need to be in a place where they need; they need to be clear, concise, concrete, and precise to be efficient and effective. The organization needs to be updated regularly to reflect changes in maintenance needs and tools. However, major causes of downtime and low availability, hence customers dissatisfaction, are often traced back to unexpected failures, leading to unexpected maintenance downtime and production costs. In general, plant and equipment failures are often caused by inefficient and ineffective maintenance, the inability to predict problems that may occur later in plants and equipment. However, with proper consideration of RAMS and risk analysis in maintenance, the number of failures can be reduced and their consequences minimized considerably. It is argued that if due attention is paid during the strategic planning to the "maintenance needs" of the system; considerable savings can be made in the operation and maintenance phases.

This paper has discussed possible ways Nigeria electric power industry can improve maintenance efforts and perhaps move from reactive maintenance to proactive maintenance. The industry has witnessed tremendous eratic power failures for decades. The dissatisfaction from the customers' demands reliability, availability, maintainability, and LCC for the plants to be of competitive advantage with the deregulation.

The maintenance processes need to be managed and organized. Suitable organizational systems and leadership therefore, have to be in place to manage the maintenance processes. It is important to integrate customer's needs, wants and preference into the management policies as early as possible. This paper argues that the integration of RAMS with risk analysis in combination with LCC in the maintenance decision is fundamental in accomplishing and ensuring the success of the organization in the deregulation era and reaching the goal set at the onset.

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