RELIABILITY PREDICTION OF ELECTRONIC EQUIPMENT OPERATION AND SUSTENANCE

1 Adesina Opeyemi Afunlehin, 2 Samuel Omolola

Department of Electrical & Electronic Engineering The Federal Polytechnic Ilaro, Ogun State, Nigeria
opeyemi.afunlehin@federalpolyilaro.edu.ng

Abstract

The paper provides enlightenment on how to create a platform for designing, implementation of accurate reliability plan for maintenance and system operation. It will go a long way if organizations can engage in practical reliability engineering techniques to meet up with certain requirements for developmental progress in the field of engineering. Therefore, the paper has attempted to give out operable state and specified conditions that can provide insights which might be an asset in enhancing engineering sectors for determining mean time between failure (MTBF) so that necessary corrective and preventive maintenance may be carried out on repairable item before catastrophe failure occur. The purposeful objective of the paper provides analysis for a critical reliability research study with required data, knowing quite well that all reliable systems experience bathtub curve in at certain period of lifetime. Electrical and electronic equipment need servicing to prolong their time frame. With prediction of MTBF, the reliability of individual component that makes up the whole system can be determine if manufacturers provide essential data about the type of components and their failure rate. However, the paper gives illustration of how MTBF of electronic components is calculated based on available database. Also, reliability predictions have contributed immensely to the growth of industrialized organizations in dealing with electronic products of all kinds for trade-off service and standardization.

Keywords: Engineering project, Reliability, MBTF, Failure rate, Maintenance, Database

Introduction

Reliability predictions is an important tool for assessment of reliability goals in engineering starting from determination of MTBF certainty, discovery of discrepancy in failure due to weaknesses in analytical design of costly project. Also the evaluation in alternative simulated in synthesis designs in case of failure of first attempt and life-cycle costs comprising of the initial cost of the item and overall maintenance to keep it ongoing during operation. More so, the necessity for provision of data in system reliability so that it is availability may be put under consideration that might involve logical implementation during failure report and availability of components for corrective action and analysis, therefore necessary supports and avenue must be available for strategy planning through which the objectives for reliability tests may be established.

Engineering is the bedrock of any meaningful infrastructural development; therefore any infrastructural expansion could serve as the basic provider in promoting industry environment. As a prerequisite for private segment, engineering designing in telecommunication equipment have catered for diversity of projects towards regional integration. The principal responsibility in engineering discipline in Nigeria project can be attributed to management policies of engineering facilities such as to provide enhancement in various sectors that can lead to economy revival and survival.

Electrical and electronic equipment is a physical structure or system that provides set of objectives that are combined to accomplish a purpose within a limited time with sustainable reliability. The extent of reliability is to provide a platform to organize plans for excellent achievement of electronic gadgets in an effective and efficient manner. As an elephant project, the timing may change due to circumstances and stochastic effects, however the main purpose being to complete the overall processes so as to achieve better responsive outcome. For any project to be regarded as being useful and effective; it is main objectives have to be visibly distinct.

Project objectives are realizable set of protocols that are proposed to be accomplished with highest degree of accuracy after testing for reliability assurance. Often time, the system or product manufacturer states the required specifications about what the project is to achieve. Provisions of indices that are measurable are also provided with expected results. Any project should be achievable and not only abstract; the project ought to be designed to solve a prominent problem that is conceptual in perspective. The relevancy of the project determines it's significant to the value of attachment. Again, all projects have time frame for completion; all executed projects are finite that is time-bound. In the same manner, the acronym SMART can be used to generalize overall project objectives of an industry with maintenance plans not often incorporated for sustainability of reliability engineering a case study of Nigeria.

Most engineering projects in Western Africa lacked maintenance practices; often times such projects already implemented suffered all kind of shortcomings within a short while because collective responsibility in maintenance is neglected. The initial cost of the project may surpass maintenance cost if precautionary measures are not put in place. The nature of project will determine the operable condition and the type of maintenance to employ for smooth running of the facility. Most industries in engineering design and processing always set a pathway for engineering personnel for execution of ideas for small and large-scale sectors. In the process of implementation, it may require extremely iterative procedures, with consideration of parts for repeated processes for others to begin, so that better and more incredible foundation are put on ground for end product. This process involves a sequence of procedures that engineers need to apply to proffer immediate solution to conceptual issues. The techniques may include the following steps, such as defining the problem occurrence, brainstorming on the solutions on how the troubleshooting would be carried out in logistic manner, designing and building a prototype of the solution by using a model, testing the solution to ensure that required response is obtained, and also improving on the existing prototype for futuristic design. However, for any design processes to have a basic root, it must start to incorporate reliability approach and testing methods through which maintenance practices are made effective and appropriate for electronic equipment in engineering.

Project designing should be seen as the early phase for mortality through which the life-cycle begins. The phase usually generates series of regarded information such as ideas of all kinds, processes to be followed to actual perfect designing, resources to be put in place to accomplish the objectives, and project delivery for execution as planned out. For any innovation for development, TVET acquisition can help in the area of energy, security and economic development in Sub-Saharan African. There is need for reliability in engineering in maintaining existence projects. All Sub-Saharan countries lacked inefficient electricity. It is high time to pay attention to other renewable resources rather than fossil fuel.

A well TVET structural programme should consider the following seven phases for project implementation which include: intake of ideas from reliable sources with professional know-how, beginning, setting up, product selection, implementation, monitoring and control and closure. In other words, these phases imply that trend of development from the start to the end of the project. In project management, life cycle procedures are characterized into four stages: initiation, planning, execution and closure.

Project implementation focuses on activities to be carried while taking actions. In project management phases, it is regarded as the third stage of the required processes when considering the stages of activities that might be involved such as: project commencement, setting up, implementation, and closure. Therefore, implementation is concerned with plan execution from the design processes that are required in engineering perspective where ideas are modeled to ensure parametric specification for standardization. With developed manpower in engineering sectors and field engineers across Sub-Saharan African, government projects should be tailored around infrastructural development such as mechanization for agricultural enhancement, electricity in term of energy for both rural and urban cities to carry out day to day activities and business. Economy condition has made every individual to become wise, therefore importation of any electronic equipment must have higher reliability and reduced maintenance costs. Every consumer this day should be concerned with products of high prediction profile as well as easy maintainability so as to enhance accurate reliability.

Reliability prediction is a good platform in instrumentation and control engineering, the reason being that it can serve as a criterion for selection of equipment for use by service providers. Reliability is a factor that can be used to determine how often equipment experiences failures when subjected to terms and condition of variability due to manipulated variables. The role of reliability prediction helps to manage engineering system for repairs and maintenance. The possibility of equipment functionality as well as continuity of service solely depends on reliability of repairable items. Therefore, reliability for engineering purposes is the probable required function to be carried out by a designed system for success outcome under specified conditions, in a specified time. Reliability as a process for prediction has provided means for application of passive and active redundant in engineering in order to have extended life span for non-repairable system. Reliability is the probability of success for a system that has engineering design and development. It can relate with mean time between failures (MTBF), through the following expression as thus:

$$R(t) = \text{Prob.}(t) = e^{-t/MTBF} = e^{-t\lambda} \quad \text{(i)}$$

Where λ is the failure rate of an exponential function

Study of reliability has shown that all items has failure rate, hence the whole system or product has the aggregate of the individual component making up the whole, and therefore it becomes easier to apply the prediction to all engineering equipment or system. With the use of metric, it becomes possible to easily evaluate the failure occurrence due to design, manufacturing weaknesses while undergoing pre-production testing of items or system.(Condra L, et al (1999).

Maintenance is the process of making certainty on a reliable physical system that has undergone repairs by ensuring that it continues to perform the usual operation it is required to do. Maintainability in engineering is the regular taken in procedures that are necessary to be followed to ensure functional and sequential servicing of system for extended service years. The follow-up actions include: service (refit), repair, inspection, replacement, modification and defect rectification. All these actions might be necessary so as to keep and ensure that the system performs as expected. Maintenance is an unavoidable aspect of engineering process despite the fact that it has no profitable output directly attached to it. In engineering activities, it is regarded as auxiliary as well as support process for stability of the entire processes. In aviation management, it is a policy that has to do with the nature of operation between life and death, to this extent, failures are not allowed and unacceptable at any moment of flight departure. Maintenance approaches can be classified specifically into two methods: Preventive maintenance which is the necessary activities that need to be carried out at predetermined and accepted intervals in order to evaluate the condition of the system for normalcy, accuracy and efficiency, however corrective maintenance is only required whenever the system has failed due to faulty components which have to be detected during the troubleshooting encounter.

Hard-time is another approach that deals with the general overhauling of the targeted system at predefined time intervals, this becomes significant because failure reporting and corrective actions are put into consideration from logistic analysis of available data (Hu, Z and Mahadevan, S (2016). From the reliability study of any component or system, it undergoes a bathtub curve as a relationship existing between failure rate and scheduled time from infant mortality stage to useful life till worn out stage is experienced, therefore this makes the overhauling of the component to be scheduled for an instant in time ahead of the increase in failures which often statistically occur (Kvassay M, et al (2017). Therefore, no failures can be prevented at infant mortality, due to de-rating in operating stresses, environmental influence and mechanical stresses. Moreover, components without a known and consistent pattern of failure as demonstrated in Fig. 1, cannot be properly maintained by a Hard-time approach according to Mendez-Gonzalez L C, et al (2017).

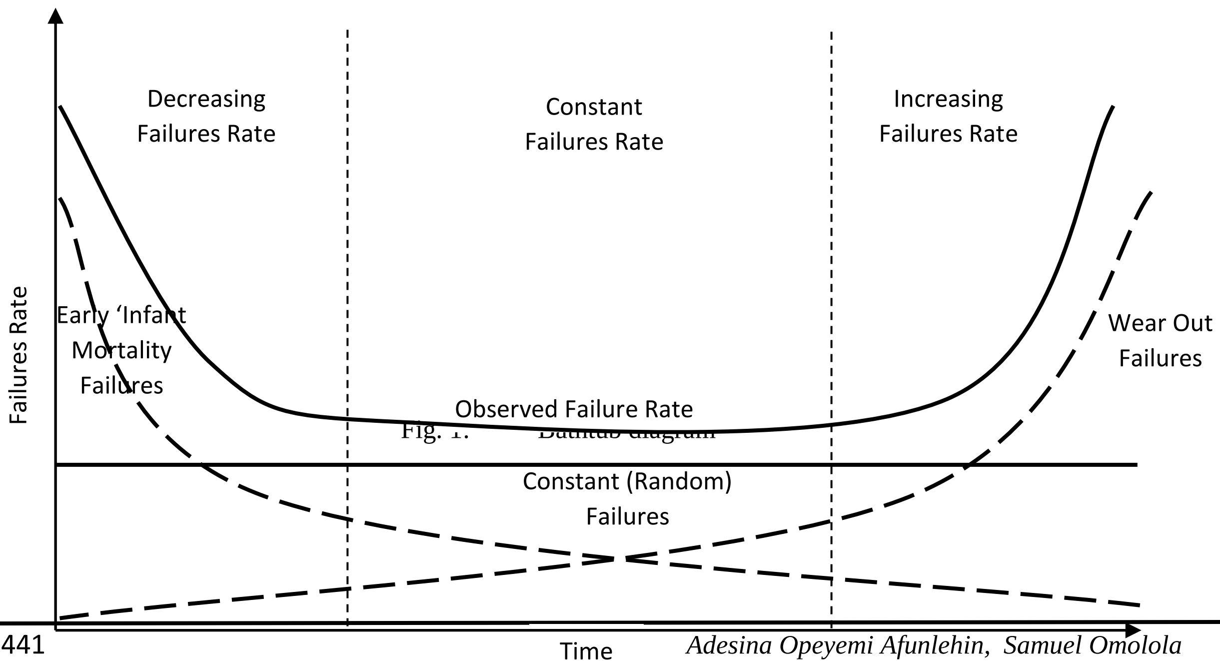

Fig. 1: Bathtub diagram

Failure is a term in reliability used to express the inability of an equipment or system to carry out a required function at expected period. For any failed equipment is regarded faulty, therefore, a failure equipment has no proficiency to perform as required task being designed for due to weakness. For this reason engineering system requires redundant for efficiency. Redundancy is the existence of two or more means, not necessarily identical, for accomplishing a given single function. That is, the inclusion of additional components or sub-systems beyond the quantity normally required for the structure to operate reliably (Windhorst J, C (2015). Therefore, in a parallel system, there is inherent redundancy, in which the failure of one or more components will not cause the system failure in as much as one of the components remains functional. Redundancy is a system design that appropriately concerns with component duplication in case of failure, others may serve as backups. However, redundancy has a negative implication because the duplication is preventable or perhaps as a result of poor planning. Redundancy prevents disruption in system operation that may result in a technical failure, hence maintaining perfect continuity in service during operation.

Maintainability refers to the degree of capability in which an equipment capacity will be retained in and restored back to serviceable operation and availability. Precautionary measures taken during developmental design and installation of a manufactured product determine the cost of required maintenance, man-hours period of engagement in the process, tools availability to enhance troubleshooting, logistic cost, skill levels of the needed personnel with facilities for implementation, so as to ensure product requirements.

Consider Tm as required repair time that has density repair function as m(t). Maintainability is therefore considered as a function with initial condition as:

$$M(t) = \begin{cases} P(0 < T_m \le t) = \int_0^t m(t)\,dt & (t \ge 0) \\ 0 & (t < 0) \end{cases}, \qquad \text{(ii)}$$

If M(t) is differentiated, then $m(t) = \frac{dM(t)}{dt} \quad (t \ge 0)$ (iii)

However, m(t) is considered to be the possibility of repairing damaged product or equipment to normal condition with a periodic change of time Δt.

Maintainability is being a function of time that deals with the probability of performing successful troubleshooting and repair action with ease and speed by restoring the system to operational status following a failure occurrence. For maintainability, time-to-repair can be regarded as the random variable while for reliability, time-to-failure is the random variable. By considering the equation of a system that has a repair time exponentially distributed. Maintainability $M(t)$ is expressed as thus:

$$M(t) = 1 - e^{-\mu.t} \qquad \text{(iv)}$$

where μ = Rate of repair

Since the maintainability refers to the probability of an event taking place for a repairable system while the reliability often refers to the probability of an event not happening (failure), hence, the maintainability can be expressed to be as system unreliability, therefore, it is assumed as $1 - R$. Besides, a single model repair rate which may be related to failure rate (λ), with respect to reliability shows exponential distribution for all kind of products.

Correspondingly, the mean for the product reliability distribution is generally obtained in relation with MTTR as described in the expression:

$$\frac{1}{\mu} = \text{MTTR (Mean Time To Repair)} \qquad \text{(v)}$$

This is however expressed as the MTTR in preference to MTTF. By expanding the distributions such as in the case Weibull distribution; the maintainability, M(t), is given as:

$$M(t) = 1 - e^{-\left(\frac{t}{\eta}\right)^{\beta}} \qquad \text{(vi)}$$

Therefore, mean time to repair (MTTR) becomes:

$$\text{MTTR} = \eta \cdot \Gamma\left(\frac{1}{\beta} + 1\right) \qquad \text{(vii)}$$

And the Weibull repair rate is given by: $\mu(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta - 1}$ (viii)

However, with respect to lognormal distribution:

$$M(t) = \int_0^{T} \frac{1}{\sigma T \sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{t - \bar{T}}{\sigma T}\right)^2} dt \qquad \text{(ix)}$$

$$M(t) = \int_0^{T'} \frac{1}{\sigma_{T'}\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{t - \overline{T'}}{\sigma_{T'}}\right)^2} dt \qquad \text{(x)}$$

where:

- $\bar{\bar{T}}$ = mean of the natural logarithms of the times-to-repair.
- $\sigma \bar{\bar{T}}$ = standard deviation of the natural logarithms of the times-to-repair.

Methodology

Reliability prediction on an equipment such as electronic may consist of these procedures:

1. List out the component parts for the equipment
2. List out hazard rate for each component part during testing analysis
3. Multiply the number of identical component part with their respective failure rate
4. Multiply the weighting factors (environmental, operating stresses) to provide an over-all product for each component type;
5. Sum the products collectively to determine the failure rate of the complete equipment.

Table 1: Characteristic failure rates of electronic components

Component	Type	Failure rate (%/1000h)
Capacitors	Paper Ceramic Electrolytic Tantalum	0.05 0.025 0.2 0.1
Resistors	Composition Wire wound Film	0.005 0.03 0.1
Transistors	Silicon Germanium	0.01 0.03
Diodes	semiconductor	0.01
Valves	Diodes Triodes Pentodes	1.0 1.8 2.2
Coils	I.F and A.F	0.5
Connections	Soldered Wrapped	0.001 0.0001
Connectors	Per used pin	0.005

Table 2: Weighting factors for operating stresses

Component	Rating	Multiply by
Resistors Transistors Diodes	0.1 of max. rating 0.5 of max. rating max. rating	1.0 1.5 2.0
Capacitors	0.1 of wkg voltage 0.5 of wkg voltage maximum wkg voltage	1.0 3.0 6.0

Illustration

An item of electronic equipment used in an office contains the following components:

- Forty (40) silicon transistors operating at 0.1 of maximum rating
- Ten (10) silicon transistors operating at 0.5 of maximum rating
- One hundred (100) diodes operating at 0.1 of maximum rating
- One hundred (100) resistors (composition) operating at 0.1 of maximum rating
- One hundred (100) resistors (composition) operating at 0.5 of maximum rating
- Fifty (50) capacitors (ceramic) operating at 0.1 of maximum working voltage
- Twenty (20) capacitors (electrolytic) operating at 0.5 of maximum working voltage
- Five hundred (500) soldered connections

With the information provided from the failure rates and the weighting factors given in tables 1 and 2, the result of the MTBF of the equipment can be determined for analysis by considering Zhang X, G, et al (2017).

Result

For the electronic system or equipment that has a normal environment, no weighting factors needed to be applied for environmental condition, therefore, the set out for calculating MTBF may be arranged as shown in Table 3.

Table 3: Determination of MTBF for reliability prediction

Component	Failure rate (λ)	Quantity (n)	Weighting (w)	Over-all component Failure rate $(\lambda \times n \times w)$
Transistors	0.01	40	1.0	0.4
Transistors	0.01	10	1.5	0.15
Diodes	0.01	100	1.0	1.0
Resistors	0.005	100	1.0	0.5
Resistors	0.005	100	1.5	0.75
Capacitors (ceramic)	0.025	50	1.0	1.25
Capacitors (electrolytic)	0.2	20	3.0	12.0
Soldered connections	0.001	500	-	0.5
Equipment failure rate				16.55

The sum of the component failure rates 16.55 per cent per 1000 hours

4. DISCUSSION

The addition of the overall component failure rates is in the final column of the table 3, as 16.55 per cent per 1000 hours. Hence, in finding the MTBF, there is need to divide this number by100000. Therefore, the reliability prediction using MTBF $= \frac{100000}{16.55} = 6000$ h

Conclusion

The integrity and reputation of an industry rest on the authenticity of the product most especially electronic equipment of all types that have flooded the market with recognized trademarks. The intention of any company in association is to provide equipment with high fit in failure as well as products that can assure MTBF for longer period after repair and maintenance. To this end, reliability prediction of any product can easily be carried without undue stress by the reliability engineers. Meanwhile, through failure reporting, analysis and corrective action system, a closed-loop for feedback path can be possible by which the user and the supplier work unanimously together to collect and record information that can be brainstormed for analysis of failures in both hardware and software engineering. The user provides a logical predetermined data which may predict the outcome of the a particular equipment during testing for pre-production so that the manufacturer of the equipment may receive informative data on improvement of products from the supplier. More so, a Failure Review Board (FRB) tends to analyze the failures, by considering crucial factors as time, money, and engineering personnel being involved in the engineering activities. The resulting analysis identifies corrective actions that should be implemented and verified to prevent failures from recurring. Most importantly, the objectives of FRACAS include the following:

- Providing engineering data for corrective action
- Assessing historical reliability performance, such as mean time between failures (MTBF), mean time to repair (MTTR), availability, preventive maintenance, etc.
- Developing patterns for deficiencies
- Providing data for statistical analysis

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