COURSE CODE: *ELE 502*

COURSE TITLE: *Reliability and Maintainability of Electrical and Electronic Systems*

NUMBER OF UNITS: *2 Units*

COURSE DURATION: *Two hours per week*

COURSE DETAILS:

Course Coordinator: **Engr O.A. Akinola**
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Office Location: **College of Engineering building**
Other Lecturers: **None**

COURSE CONTENT:

Introduction to reliability, maintainability, availability and elementary reliability theory.Application to power systems and electronic components.Tests of fault.Designing for higher reliability.Packaging, mounting, ventilation, protection from humidity and dust.

COURSE REQUIREMENTS:

This is a compulsory course for all 500 level students in the College of Engineering. In view of this, students are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination.

READING LIST:

LECTURE NOTES

Definition of Reliability

Reliability when applied to engineering devices or systems is defined as 'the probability that the system will operate to an agreed level of performance for a specified period, subject to specified environmental conditions'. Thus the reliability of a small computer might be given as 80% over a 200hr period, with an ambient temperature off 25degree C and no vibration. It is important that the entire environment should be specified completely.

What is Reliability worth?

Reliability is but one characteristic of an electronic device or system which must be considered when selecting one of a number of alternative designs. From the user's viewpoint, the most rational criterion for deciding which design is best is that of minimum total life cost. The total cost for all activities during the life of the equipment is used as a criterion of value, and the arrangement giving the least total life cost is adopted. Equipment reliability then becomes an important parameter in the design. As it increases, the cost of buying equipment to be held in reserve in case of failure, the cost of spare replacement parts, and the cost of maintenance staff all decrease. However, the cost of design and development, and the initial purchase price all increase very rapidly as more effort is devoted to increasing reliability. There is thus a stage beyond which no economic benefit can be obtained from any increase in reliability.

As the scope of electronics widens and equipment of greater power and sophistication becomes technically feasible, an increasing number of applications arise in which a major requirement is high reliability. Thus there is continual pressure to develop components which have greater reliability, and system design techniques which can produce more reliable systems from existing components.

- **Mean Time between Failures**

One disadvantage of reliability as an index of performance is the need to specify a particular operating period for the equipment. If the same equipment is operated for a different period, its reliability will be different.

The most useful measure of performance which does not involve the period of observations is the mean time between failure (MTBF). The MTBF M of a system may be measured bytesting it for a total period T, during which N faults occur. Each fault is repaired and the equipment is put back on test, the repair time being excluded from the total test time T. The observed MTBF is given by:

$$M = \frac{T}{N}$$

This observed value is not necessarily the true MTBF since the equipment is usually observed for only a sample of its total life.

Another way of expressing equipment reliability is the failure rate; that is, the number of faults per unit time. For many electronic systems, the failure rate is approximately constant for much of the working life of the equipment. Where this is the case, the failure rate λ is the reciprocal of the MTBF.

$$\lambda = \frac{1}{M}$$

- **Mean Time To Failures**

The MTBF is a measure of reliability for repairable equipment; a similar measure is useful for components such as thermionic valves, resistors, capacitors, transistors, etc which are items that cannot be repaired. The correct measure for these components is the Mean Time to Failure (MTTF).

This may be calculated from the results of life testing as follows: Let a set of N items be tested until all have failed, the times to failure being t_1, t_2, t_3,... , t_n. .Then the observed MTTF is given by:

$$M = \frac{1}{n}\sum_{i=1}^{n} t_i$$

$$\lambda = \frac{1}{M}$$

if λ is independent of time.

- **Availability A**

This is measured from the funning log of the machine by dividing all of the 'switched-on' time of the machine in a given period into two categories- up-time U, during which the machine is in working order and down-time D during which the machine is faulty or being repaired.

$$A = \frac{U}{U + D}$$

For an idealised system in which the component failure rate is constant, the availability has an asymptotic value given by:

$$A = \frac{M}{M + R} = \frac{\mu}{\mu + \lambda}$$

Where M = MTBF and R = Mean Repair Time.

Unavailability may be defined in the same way as the availability; it is the proportion of time that a system is not in working order.

Generalised Definitions of Failure Rate and MTBF

The probability of system failure over a given period F(t) is complementary to the system reliability R(t) over the same period, since no other outcome is possible, and these two are mutually exclusive;

Thus, $F(t) + R(t) = 1$.

Probability distribution function is defined as: $f(t) = \frac{dF(t)}{dt} = -\frac{dR(t)}{dt}$

Hence $F(t) = \int_0^t f(t)dt$

After a period, n_s will survive and $n_f = n_0 - n_s$ will have failed.

$$\lambda = \frac{1}{ns} * \frac{dnf}{dt}$$

$$R(t) = \frac{ns}{n0} = 1 - \frac{nf}{n0}$$

$$\frac{dR(t)}{dt} = -\frac{1}{ns} * \frac{dnf}{dt}$$

$$\lambda = \frac{1}{ns}(n0 * \frac{dR(t)}{dt})$$

$$\lambda = \frac{1}{R(t)} * \frac{dR(t)}{dt}$$

Reliability Prediction

System Subdivision

The first requirement to investigate the reliability of complete systems is to divide the system into units, each small enough to enable its reliability to be assessed directly. We define a component as an item which cannot be subdivided without destroying it, or as the smallest item which could be replaced when repairing a fault.

Reliability Models

Reliability model (diagram) is a useful analytical tool for predicting system behaviour. This illustrates the functional relation between the various components of the system and the way in which a failure of each component would affect the overall system performance.

Series system is the simplest arrangement is one in which each component is necessary for correct operation of the system, and in consequence a failure of any one component must cause a system failure. If the separate reliabilities of five series connected components are R_1, R_2,R_3, R_4, R_5, the overall reliability is $R = R_1 * R_2 * R_3 * R_4 * R_5$.

Failure Analysis of Series System

Since in a series system, a failure in anycomponent will cause a system failure. The probability required is the probability that component 1, component 2 or component 3 will develop a fault during a prescribed interval. If the separate probabilities are mutually exclusive, the joint probability is found by the addition rule i.e. $P= p_1 + p_2 + p_3 + p_4+ p_5$.

Parallel Systems

In these systems, more than the minimum essential equipment is used, with the object of improving the system reliability. More than one way of meeting the functional requirements of the system is implemented so that the failure of one component does not ground the system. Significant improvement in reliability is achieved in such systems generally referred to as a redundant system. A simple way of introducing redundancy is to use alternative subsystems simultaneously with some switching mechanism at the output terminal which enables faulty subsystems to be disconnected.

In this situation it is simpler to calculate the probability of failure than the reliability directly. Given that three components are connected in parallel so that a system failure can only occur when all three of the subsystems have failed.

The probability of this is given as: $P_s = p_1 * p_2 *p_3$ where p_1, $p_{2,}$ p_3 are the probabilities of failure in each of the three subsystems in some specified interval of time. The system reliability $R = 1 - P_s$.

While in some parallel systems, one subsystem alone could meet the functional needs, in a number of others more than one subsystem may be needed. In general we may have n parallel subsystems and require r of them to be effective for the system to function. This is sometimes called an 'r out of n' system.

Mixed Systems

A number of engineering systems combine series and parallel sections. This arrangement is frequently used where some part of the system is particularly prone to failure.

Use of Redundancy

In general terms a redundant system may be defined as one which has more than one way of producing the specified output.