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Some Techniques to Increase Reliability of Systems

A Research

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

﴿ قَالُواْ سُبْحَانَكَ لاَ عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ ﴾

صدق الله العظيم

الآية (32) سورة البقرة

List of Figure

List of Symbols

Symbols	Description
R(t)	Reliability
λ	Failure rate
MTTF	Mean Time to Failure
h(t)	Hazard rete
f(x)	Probability density function(p. d .f)
F(x)	Cumulative distribution function (c.d.f)
p(t)	Probability
R_s	systems reliability
Rs_1	Reliability of first component
Rs_2	component second of Reliability
Rs_3	Reliability of third component

Acknowledgments

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My heartfelt gratitude goes to him. My thank is also extended to all members of the Mathematics Department (University of Babylon, College of Education for Pure Sciences) for their help and encouragement. I can never express adequately my appreciation towards them. Finally, I would like to express my deepest appreciation to my family and friends for supporting and encouraging me throughout the years of my study

Dedication

To my parents, who were the reason of what I became today, thanks for your great support and continuous care. To my brothers, sisters ,wife and my children And to everyone who supported me to reach this success.

List of Contents

Abstract

In this research, we test the assignment of reliability for mixed systems by using series unit process reduction, which allows to simplify these systems to simpler computation for series system. Also, we introduced two techniques in order to addressed the reliability allocation for mixed system. Also, we will look at the importance of each unit in a mixed system and attempt to estimate the impact of their effect on the system's overall performance depending on their importance. We will also demonstrate how to use an addition technique to enhance the efficiency of the units that have a greater impact on the system's overall performance than others.

Introduction

The vital importance of reliability in a number of systems draws many researchers to reliability engineering [16]. For design issues with reliability criteria, a lot of work has been performed, and a number of techniques have been used. According to Tzafestas in 1980, one of the undeniable phases in the design of such multi-component structures is the problem of using usable tools. most cost-effective way to increase overall system efficiency or decrease resource consumption while achieving specific reliability goals [17]. The variety of system configurations, resource limitations, and options for optimizing performance have prompted the creation and analysis of several optimization models. On a regular basis, surveys on improving reliability have been written.

One of the most recent publications on the subject is Kuo et albook. Several studies have been conducted to improve parallel–series systems, however, only a handful have focused on series–parallel systems. The bulk of these works are on Jensen's redundancy allocation system from 1968 [18]. use complex programming for series–parallel–series networks He believes the networks under scrutiny are made up of a series of blocks, each of which is made up of related technology that work in concert. In multi-state series–parallel systems, Marquez and Coit recently introduced a heuristic for allocating redundancy. They proposed a novel solution strategy that has a number of distinct advantages over conventional approaches to the problem [19, 20]. Levitin et al., Zuo Hoang Pham, and

Introduction

Venugopal all suggest solutions to the problem of redundancy optimization in general. The subject of this series–parallel systems is the reliability allocation problem, in which the reliability of the modules must be calculated in order to reduce the utilization of a resource under a reliability constraint. When several technologies of the same purpose are used in parallel, this issue occurs [20, 21].

In 1972, Kim, Y. H., et al gave the algorithm a list of possible routes from the source to the graph sink to calculate system reliability based on route data. A network is reliable when a route connects every pair of nodes. Reliability analysis of networks such as networks for computer architecture and data communication networks.

In 2015, Hassan, Z. A. H. and Balan, V. [46] introduced the quadratic case of reliability, to make use the convex/concave mutual dependence of slice components along the curves of constant-slice reliability, in order to maintain or increase the circuit reliability. Clear techniques of engineering to evaluate the reliability of electrical systems used in aircraft show that elements of reliability must be linearly based on time [36]

In 2016, Mutar, E. K.,and Hassan, Z. A. H. presented reliability of oxygen

supply system for spacecraft and some engineering characteristics [35].

Hassan, Z. A. H.and Mutar, E. K., have presented geometry of reliability models of lectrical system usedinside spacecraft

Introduction

In 2019, Sulaiman, H.K., and Hassan, Z. A. H., introduced a study of mathematical models in reliability of networks, The researchers have introduced accurate ways to calculate reliability complex systems to calculate the reliability of the electromagnetic system inside aircraft and some engineering features.

Also, the researcher has studied some ways to allocate reliability to the subsystem. As well as studying the reliability allocation and optimization of the reliability of the electromagnetic system within an aircraft by the genetic algorithm and the particle swarm optimization[50] .

The goal of this research is to calculate the reliability of the mixed system and improve the reliability of each components, and we used some methods to increase the reliability of the mixed system. This research consists of four chapters;

Chapter One contains some definitions and concepts. Chapter Two is the study of certain types of systems that work to clarify the idea of the function of the structure. Chapter Three contains some ways to solve the mixed system.Chapter four contains of conclusions and future works .

Chapter one

Reliability and Probability

1.1 Introduction

In this chapter, relevant definitions, basic concepts and the background required for this research are presented. Two sections in this chapter, the first section contains some of the basic definitions and graph theory that we need in the research. The second section provides the basic definition of the reliability function and reliability network and some important definitions that we need in this work.

1.2 Basic Definitions and Concepts

Definition (1.2.1) Probability p(t) [37]

Probability is a numerical measure of the likelihood of an event in comparison to a set of possible outcomes. When flipping a coin, for example, there's a 50% chance of seeing heads vs tails (assuming a fair or unbiased coin) Probability Properties P(B) is the probability of an occurrence B, and it has the following properties

1) $0 \leq P(B) \leq 1$

2) $P(B) = 1 - P(B)^c$

3) $P(\emptyset) = 0$

4) $P(S) = 1$

In other words when an event is certain to occur it has a probability equal to (**1)** and when it is impossible to occur it has a probability equal to (0) it can be shown that the probability of the union of two events A and B is

$$P(A\cup B) = P(A) + P(B) - P(A\cap B) \quad (1.1)$$

Similarly the probability of the union of three events A , B and C is given by :

$$P(A \cup B \cup C) = P(A) + P(B) + P(C) - P(A\cap B) - P(A\cap C) - P(B\cap C)$$

$$+ (A\cap B\cap C) \quad (1.2)$$

Definition (1.2.2) System [16,38]

A collection of compounds in a specific order that communicate in order to perform with each other and with external components or other structures given purpose. Definition

(1.2.3) Reliability [22,39]

The probability that for a certain period of time the system will survive is established This can be expressed as the time to system failure in terms of random variable T. The probability of survival or reliability R(t) at time t, has the following properties:

1) $0 \leq R(t) \leq 1$

2)R $(\infty) = 0$, no device can work forever

3) R(0)= 1 the device is assumed to be working properly at time t = 0

4)R (t) in general is a decreasing function of time t.

$$(t) = \{T > \ \} \quad (1.3)$$

$$R(t) = 1 - \int_0^t f(t)dt \quad (1.4)$$

Or

$$R(t) = \int_{t}^{\infty} f(t)dt \qquad (1.5)$$

Definition (1.2.4) Mean Time to Failure (MTTF)[40]

This is a simple metric of reliability for non-repairable systems. Under specified conditions, the average time between failures during a measurement cycle.

$$MTTF = \int_{0}^{t} t\, f(t)dt \qquad (1.6)$$

Or

$$MTTF = \int_{0}^{\infty} R(t)dt \qquad (1.7)$$

Definition (1.2.5) Hazard Rete h(t)[50]

is the rate of immediate failure, and is the maximum rate of failure, both indicated by the symbol h(t), where the rate of change is the chance that the remaining product will fail in the next several time periods the equation can be written as follows:

$$h(t) = \lim_{\Delta t \to 0} \frac{F(t+\Delta t)-F(t)}{\Delta t R(t)} = \frac{f(t)}{R(t)} \qquad (1.8)$$

The Hazard rate unit is the failure cases per unit time t

Definitions(1.2.6) Probability Density Function(p. d .f)[49]

Is a symbol of continuous functions only and is symbolized by the symbol (p.d.f) If x is a random variable the probability function is f(x) and $a \leq x \leq b$ so it is a function,

$$p(a \leq x \leq b) = \int_{a}^{b} f(x)dx \quad and \quad f(x) \geq 0 \quad , \quad for\ all\ x \qquad (1.9)$$

Definitions (1.2.7) Cumulative Distribution Function (c.d.f)[48]

The cumulative distribution function (c.d.f) is a random variable x function F(x) that is defined for a number x by:

$$F(x) = (X \le x) = \int_{-\infty}^{x} f(s)ds \qquad (1.10)$$

$$F(x) = \int_{-\infty}^{x} f(s)ds \qquad (1.11)$$

Conversely:

$$f(x) = \frac{d(F(x))}{dx} \qquad (1.12)$$

The value of the c.d.f at x is the area under the probability density function up to x if so chosen. It should also be pointed out that the total area under the p.d.f is always equal to or mathematically.

Definitions(1.2.9) Conditional Probability[47]

The probability of one of two events A and B happening knowing that the other event has already occurred is known as conditional probability. Provided that B has already occurred, the expression below denotes the likelihood of an occurring

$$P({}^{A}/_{B}) = \frac{P(A \cap B)}{P(B)} \qquad (1.13)$$

Definitions (1.2.10) Conditional Reliability Function[35]

Conditional reliability is defined as the probability that a component or system will operate without failure for a mission time t given that it has already survived to a given time t mathematically this is expressed as [1,0].

$$R(t\ /\ T)\ =\ R(t+T))/(R(t) \qquad (1.14)$$

Definitions (1.2.11) Reliability Allocation[43]

The process of assigning reliability requlrements to individual reliability is called reliability allocation.

1.3 Relations between F(t) , f(t) , R(t) and h(t)

All of the functions F(t), f(t), R(t), and h(t) can be transformed into each other Consider the example below:

$$F(t) = \int_0^t f(x)dx \qquad (1.15)$$

This leads

$$f(t) = \frac{dF(t)}{dt} = -\frac{dR(t)}{dt} \qquad (1.16)$$

And $R(t) = 1 - F(t)$ (1.17)

According to equation (1.8) , $h(t) = f(t)/R(t)$

we compensate for its equation(1.16) in its equation (1.8) we get

$$h(t) = \frac{-dR(t)}{dt} \times \frac{1}{R(t)} \qquad (1.18)$$

and from them we get

$$\frac{dR(t)}{R(t)} = -h(t)dt \qquad (1.19)$$

Integrity of the parties ,

$$\ln R(t) = -\int_0^t h(x)dx \qquad (1.20)$$

And taking the exponential of both sides equation we get

$$R(t) = e^{-\int_0^t h(x)dx} \qquad (1.22)$$

Also we can obtain R(t) from its equation (1.8)

$$R(t) = \frac{f(t)}{h(t)} \qquad (1.23)$$

Then :-

$$f(t) = R(t)\, h(t)$$

And

$$f(t) = h(t)e^{-\int_0^t h(x)dx}$$

Chapter Two

Reliability System

Chapter Two

Reliability Systems

2.1 Introduction

We looked at some unwavering quality concepts in the previous chapter, such as the Hazard rate mean time to failure, and so on, and we looked at a indicant portion of the work that has been done in this region. This section considers he framework's dependability. This necessitates a thorough understanding of the physical structure of the mechanism, which may range from small to large and include various segments. It also necessitates an appropriate colleague with he framework's concept in the event of subsystem failure.

This chapter is divided into two parts. The second section includes a basic system and includes series , parallel , series – parallel , parallel - series, combination of series and parallel and K-out of – n framework. In the last part of this chapter we will examine the Mixed system which is important for difficult situations or systems , which is not easy to identify the components whether series or parallel ,and we will learn about some ways to solve the Mixed system[44].

2.2 Systems Reliability

2.2.1 Simple System

Certain types of system frequently arise in practice and serve to illustrate the idea of the structure function . If it is not possible to solve a problem by using the simple structure of this section , it may be possible to solve the problem by viewing it as a combination of simple structure . The ways by which the system element can be combined are the following[43] :

1- In series.

2- In parallel.

3- In parallel – series.

4-In series – parallel.

5- Mixed system.

6- K – out – of – n parallel configuration.

2.2.1.1 Series system

The series system works only if all of its components are working. This system depends on both of them[47] .Device elements are executed properly

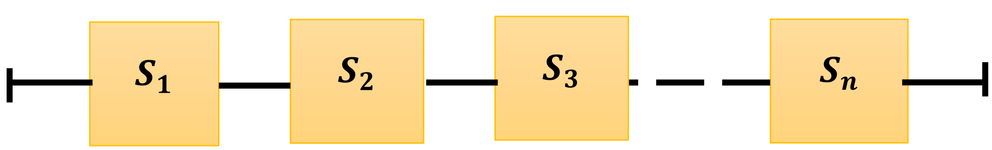


Figure (2.1) Series system

the reliability of the system is given by

$$R_{system} = R_{S1} \times R_{S2} \times \ldots \times R_{Sn}$$

$$R_{system} = \prod_{i=1}^{n} R_{si} \qquad (2.1)$$

Notes

1) In this way the reliability of the system and its R_S is smaller than the reliability of any component.

2) This is one of the easiest and weakest ways because when one of the components fails it leads to the failure of the entire system[42].

3) If the reliability of all components is equal $R_1 = R_2 = R_3 = \dots = Rn$ are called identical and independent thus the reliability of the system

$$R_{systeem} = R^n \qquad (2.2)$$

Example (2.1)

Consider a system with three components connected in series, each with a fixed failure rate. (In other words, the components' lifetimes are exponential)

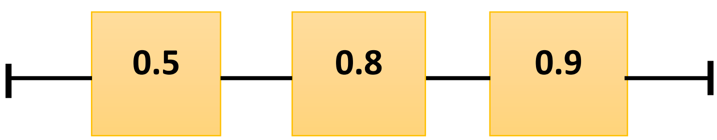


Figure (2.2) Example of series system

hose rates per (10,000) hours for components $A_1 = 0.5$, $B_1 = 0.8$, and $C_1 = 0.9$, respectively. As a result, we have a constant failure rate.

Solution:-

We can solve the example in two ways:

First method $R(t) = e^{-\lambda t}$

Then:12

$R_{A1}(t) = e^{-0.5t}$

$R_{B1}(t) = e^{-0.8t}$

$R_{C1}(t) = e^{-0.9t}$

Hence the reliability of the system is :

$R_s(t) = e^{-0.5t} \times e^{-0.8t} \times e^{-0.9t}$

$R_s(t) = e^{-(0.5+0.8+0.9)t}$

$= e^{-2.2t}$

The rliability that the machine will continue to function after 10,000 hours, for example.

$R_s(1) = e^{-2.2(1)}$

$= e^{-2.2} = 0.1108$

Second way we find the reliability of each component and then find the reliability of the system

$R_{A1} = e^{-0.5t} = e^{-0.5(1)} = 0.606$

$R_{B1} = e^{-0.8(1)} = 0.4493$

$R_{C1} = e^{-0.9(1)} = 0.4066$

Then :

$R_s = R_{A1} \times R_{B1} \times R_{C1}$

$R_s = 0.606 \times 0.4493 \times 0.4066$

$R_s = 0.1108$

2.2.1.2 Parallel System

For a parallel system to succeed, at least one of the components must succeed. For a system with n statistically independent parallel components, the probability of failure, or unreliability, is the probability that component 1 fails,

component 2 fails, and all other components in the system fail Putting another way, if component 1 succeeds or component 2 succeeds or any of the (n) components succeeds the system succeeds[48]. The structural role of a system is defined by As a result, the system's reliability (assuming independent failures) is

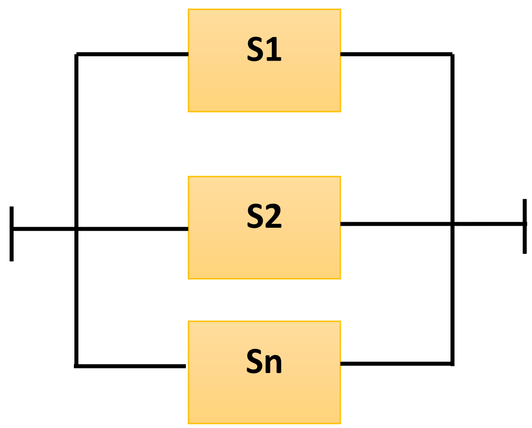


Figure (2.3): Parallel system.

The reliability of the system (again assuming independent failures) is then:

$$R_{system} = 1 - P(\,all\,fail\,)$$

$$= 1 - [P(\,S_1\,fails\,) \times P(\,S_2\,fails\,) \times \ldots \times P(\,S_n\,fails\,)]$$

$$= 1 - (\,1 - R_1\,) \times (\,1 - R_2\,) \times \ldots \times (\,1 - R_n\,)$$

$$R_{system} = 1 - \prod_{i=1}^{n}(1 - R_i) \qquad (2.3)$$

Example (2.2)

Find the reliability of the system shown where the number in brackets indicates the constant failure rates pet year for of the components.

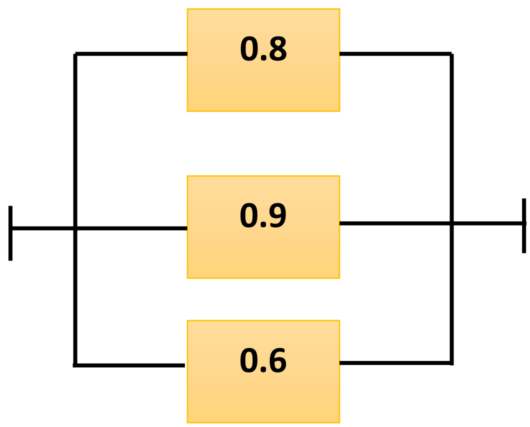


Figure (2.4) Example of parallel system

Solution:

The device components are linked in parallel, and each component's failure rate is :

$\lambda_1 = 0.8 \quad , \quad \lambda_2 = 0.9 \quad , \quad \lambda_3 = 0.6$

The dependability of each variable must be proven.

$$R(t) = e^{-\lambda t}$$

$$R_1(t) = e^{-0.8t}$$

$$R_2(t) = e^{-0.9t}$$

$$R_3(t) = e^{-0.6t}$$

$$R_s(t) = 1 - (1 - R_1(t))\big(1 - R_2(t)\big)\big(1 - R_3(t)\big)$$

$$R_s(t) = 1 - [(1 - e^{-0.8t})(1 - e^{-0.9t})(1 - e^{-0.6t})]$$

$$R_s(t) = 1 - [(1 - e^{-0.9t} + e^{-0.8t} + e^{-1.7t})(1 - e^{-0.6t})]$$

$$R_s(t) = 1 - (1 - e^{-0.6t} - e^{-0.9t} + e^{-1.5t} - e^{-0.8t} + e^{-1.4t} + e^{-1.7t} - e^{-2.3t})$$

$$R_s(t) = e^{-0.6t} + e^{-0.9t} - e^{-1.5t} + e^{-0.8t} - e^{-1.4t} - e^{-1.7t} + e^{-2.3t}$$

Then for example the probability that the system is still working after1000 hours is :

$$R_s(1) = e^{-0.6(1)} + e^{-0.9(1)} - e^{-1.5(1)} + e^{-0.8(1)} - e^{-1.4(1)} - e^{-1.7(1)} + e^{-2.3(1)}$$

$$R_s(1) = 0.5488 + 0.4066 - 0.2231 + 0.4493 - 0.2466 - 0.1827 + 0.1003$$

$$R_s(1) = 0.85$$

There is a 85% chance that such a system will still be working after 1000 hours.

2.2.1.3 Parallel-series system[49]

The reliability of a system consisting of m of related groups in the form of a parallel – series and each set containing n components as shown in Figure (2.5) .

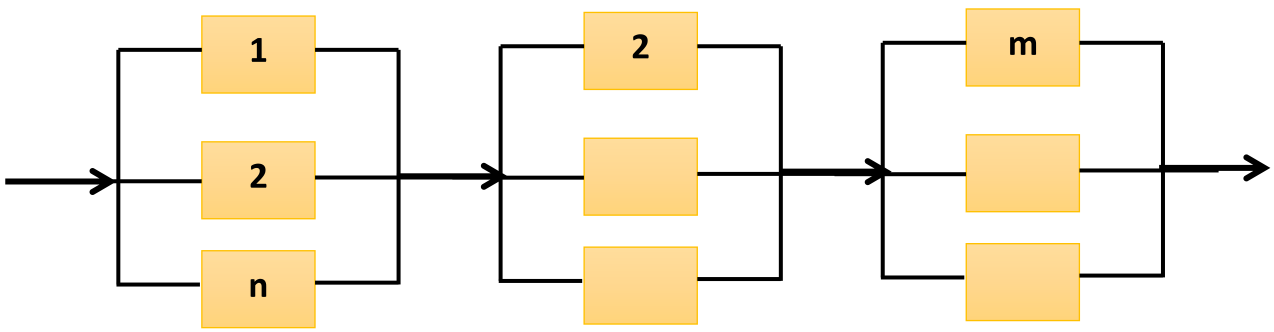


Figure (2.5) Parallel - series system

$$R_s = [1-(1-R)^n]^m \qquad (2.4)$$

Or

$$R_s = [R_q]^m$$

Where $R_q = 1-(1-R)^n$ (2.5)

Example (2.3)

Find the reliability of the system shown in Figure (2.6) if you know that the fixed failure rate for each year is 0.09 for each component.

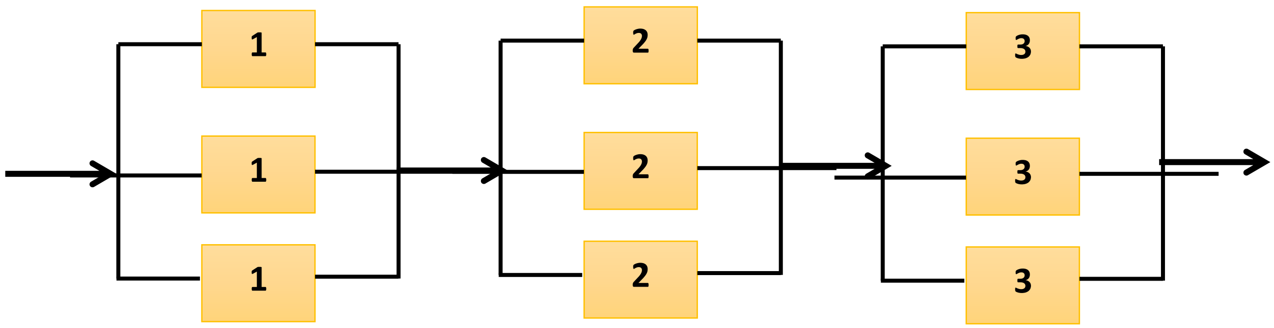


Figure (2.6) Example of parallel series

Solution:

We must first find the reliability of each component

$R = e^{-\lambda t}$

$R = e^{-0.09t}$

$R = e^{-0.09(1)}$

$R = e^{-0.09}$

$R = 0.91$

It is considered reliability for each component. We can use equation (2.4) to find the reliability of the system $m = 3$, $n = 3$

$R_s = [1-(1-R)^n]^m$

$R_s = [1-(1-0.91)^3]^3$

$R_s = [1-(0.0007)]^3$

$R_s = 0.99$

2.2.1.4 Series – parallel system

The parallel – series structure is the inverse of the series – parallel structure. We study as system of components arranged so that there are mm sub system operation in series each sub system consisting of nn identical components in parallel such an arrangement is called series – parallel arrangement Applications of such systems can be found in the areas of communication networks and nuclear power systems we get the reliability of such as system[41]

$$R_s = 1 - \left(1 - \prod_{i=1}^{m} r_i\right)^n \tag{2.6}$$

The series – parallel configuration is shown in figure (2.7)

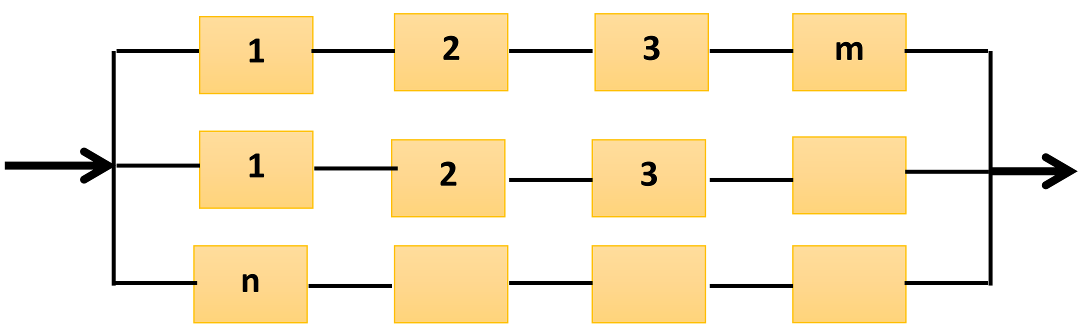
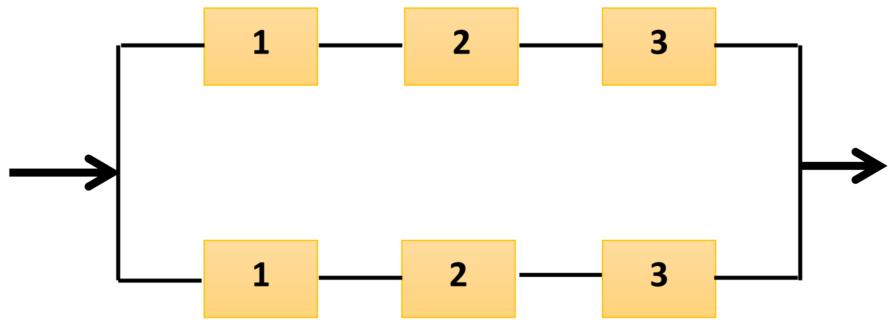


Figure (2.7) series – parallel system

Example (2.4)

Calculate the reliability of the system shown in the following figure below if you know that the reliability of its components is $R_1 = 0.98$, $R_2 = 0.96$, $R_3 = 0.92$



Figure(2.8) Example of series parallel

Solution

Note that the system is series – parallel it contains two lines and three components per line that means $n = 2, m = 3$ we can use equation (2.6)

We get

$$R_s = 1 - \left(1 - \prod_{i=1}^{m} r_i\right)^n$$

$$= 1 - \left(1 - \prod_{i=1}^{m} r_i\right)^2$$

$$= 1 - [1 - (0.98 \times 0.96 \times 0.920]^2$$

$$= 0.98$$

2.2.1.5 Mixed System

This system is a combination of a parallel system and a series system, and we only break the system into a series and parallel to find each subsystem's reliability and complete to find the system's reliability[40].

Example(2.5)

Find the reliability of the system shown where the number in brackets indicates the constant failure rates per year for each of the components.

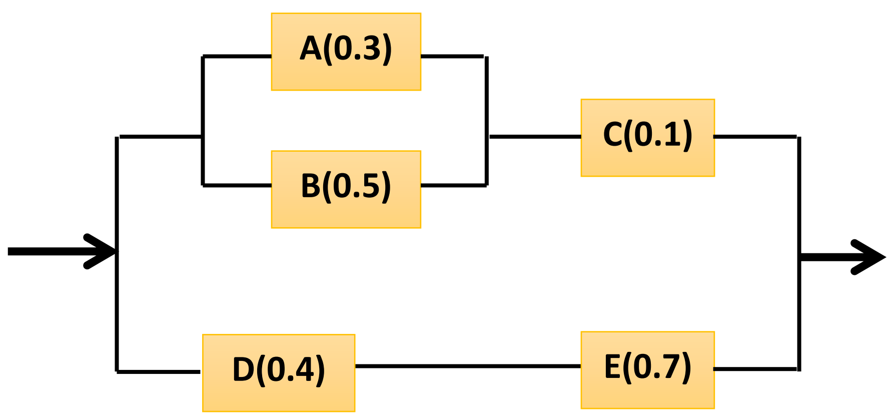


Figure (2.9) Example of Mixed system

Solution:

Consider the three branches (ABC) and (DE) first these are both series subsystem then reliability ABC is

$$R_{ABC}(t) = 1 - \left[(1 - R_A(t))(1 - R_B(t))\right] \times R_C(t)$$

$$= 1 - [(1 - e^{-0.3t})(1 - e^{-0.5t})] \times e^{-0.1t}$$

$$R_{ABC}(t) = e^{-0.6t} + e^{-0.4t} - e^{-0.9t}$$

$$R(1) = 0.9$$

And reliability DE is

$$R_{DE}(t) = R_D(t) \times R_E(t)$$

$$= e^{-0.4t} \times e^{-0.7t}$$

$$R_{DE}(1) = e^{-1.1t} = 0.34$$

Now look at the two subsystems (ABC) and (DE) as part of a larger system which is parallel system

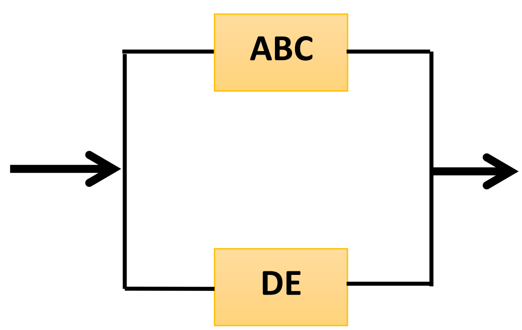


Figure (2.10) parallel system

We find system reliability

$$R_{system} = 1 - \left[(1 - R_{ABC}(t))\left(1 - R_{DE}(t)\right)\right]$$

$$= 1 - [(1 - 0.9)(1 - 0.34)]$$

$$R(1) = 1 - 0.066 = 0.93$$

2.2.1.6 k – out – n Parallel System

This system is considered a special case of parallel redundancy where this method needs to succeed in working on at least the k components of the total n components.

Al though this system is a special case of parallel redundancy in some cases it is a general configuration because the number of units required to maintain the success of the system is close to the total number of units in the system and the behaviour of the system is close to the series system if the number of units required equals the number the units in the system is thus a series system[42].

Example (2.6)

The web host has three serves independent and indentical and connected in parallel must work at teats two of them to keep the web service running and not interrupted the servers are must work at teats two of them to keep the web service running and not interrupted the servers manufactured by different companies and have different reliability is $R_A = 0.87$, $R_B = 0.92$, $R_C = 0.85$

and they have the sometime as the task

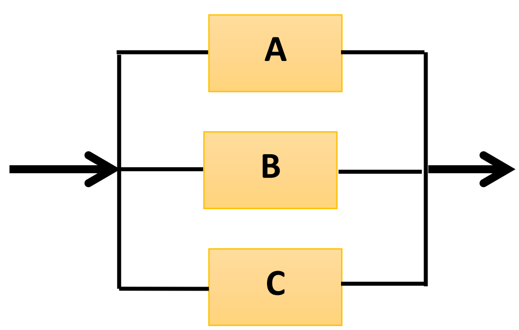


Figure (2.11) Example of k – out – 3 parallel system

Solution:-

Because it must work on at least B servers out of C servers, only one is permitted to fail. This is a B out C set. For system success, the following operations can be carried out:-

1) All C servers are working .

2) The A fails and the A and B and C works.

3) The B fails and the A and A and C works.

4) The C fails and the A and A and B works.

We can calculate system reliability as follows:

$$R_{system} = R_A R_B R_C + (1 - R_A) R_B R_C + R_A (1 - R_B) R_C + R_A R_B (1 - R_C)$$

$$= R_A R_B R_C + R_B R_C - R_A R_B R_C + R_A R_C - R_A R_B R_C + R_A R_B - R_A R_B R_C$$

$$= R_A R_B + R_B R_C + R_A R_C - 2 R_A R_B R_C \qquad (2.7)$$

$$R_S = (0.87 \times 0.92) + (0.92 \times 0.85) + (0.87 \times 0.85) - 2(0.87 \times 0.92 \times 0.85)$$

$$R_S = 0.96$$

Chapter Three

The Reliability Allocation for Mixed Systems

Chapter Three

The Reliability Allocation for Mixed Systems

3.1 Introduction

We are addressing reliability allocation models of mixed systems in this chapter. the aim of this allocation is to use the reliability model to allocate the subsystems to reliability in order to achieve the systems defined reliability objective [5,7]. models of reliability allocation are developed and techniques are presented in this paper to solve the problem. If the system consists of n component that works satisfactorily when at least k of the n comports are good Sheath [1962] and Balaguraumy [1977] studied the methods of calculating the reliability of the various systems and presented the concept of redundancy which means using additional components in the system. Hence if one of the system components felled then the system would go no working the accompanying components an example of this is the use of double wheel vehicles and bridge pillars. Redundancy is necessary when failure has destructive outcomes like a failure in spaceships or in artificial hearts.[45]

3.2 Mixed System [10, 11,24]

This system is a combination of a parallel system and a series system, and we only break the system into a series and parallel to find each subsystem's reliability and complete to find the system's reliability

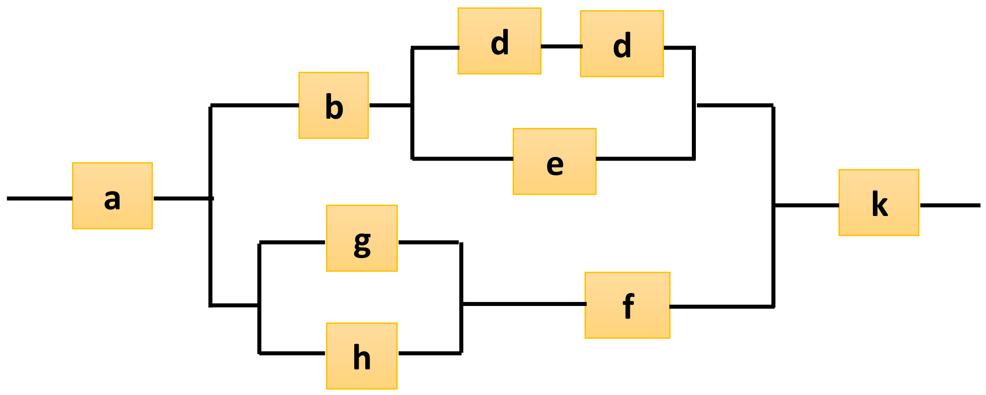


Figure (3.1) mixed system

3.2.1Reduction to Series Elements

This method involves replacing each parallel path systematically with an identical on Single path, and the structure is gradually reduced to one consisting only of component [9, 12]

In this section, will try to find the reliability function of mixed system Figure. (2.2) as the within steps.

Step1

$$S_1 = 1 - [(1 - R_{cd})(1 - R_e)]$$

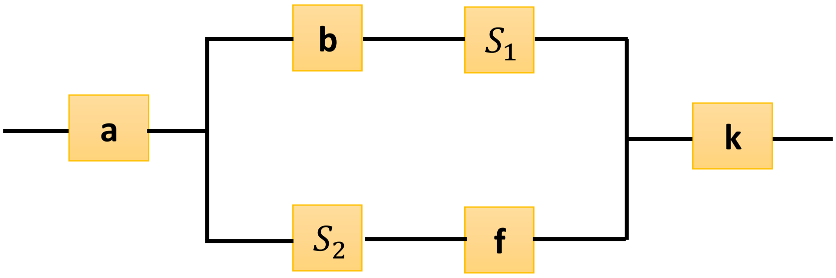
$$= 1 - [1 - R_e - R_{cd} + R_{cd}R_e]$$

$$= R_e + R_{cd} - R_{cd}R_e$$

$$S_2 = 1 - \left[(1 - R_g)(1 - R_h)\right]$$

$$= 1 - \left[1 - R_h - R_g + R_gR_h\right]$$

$$= R_h + R_g - R_gR_h$$



Figure(3.2) step1

Step2

$$S_3 = R_b \times R_{S_1}$$

$$S_4 = R_{S_2} \times R_f$$

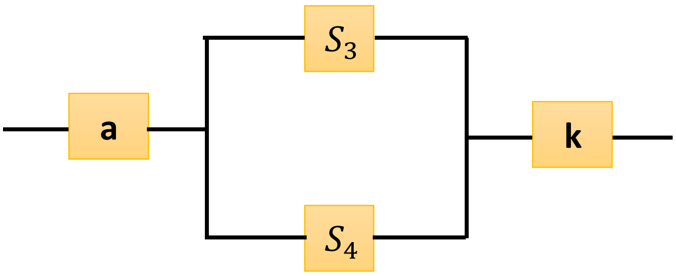


Figure (3.3) step2

Step3

$$S_5 = 1 - \left[(1 - R_{S_3})(1 - R_{S_4})\right]$$

$$= 1 - \left[1 - R_{S_4} - R_{cd} + R_{S_3} R_{S_4}\right]$$

$$= R_{S_4} + R_{S_3} - R_{S_3} R_{S_4}$$

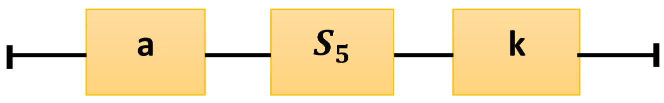


Figure (3.4) step3

Step4

$$R_{system} = R_a \times R_{S_5} \times R_k$$

We will study the reliability allocation of this system in the following sections

.

Example(3.1)

Find the reliability of the system shown Figure(3.5)

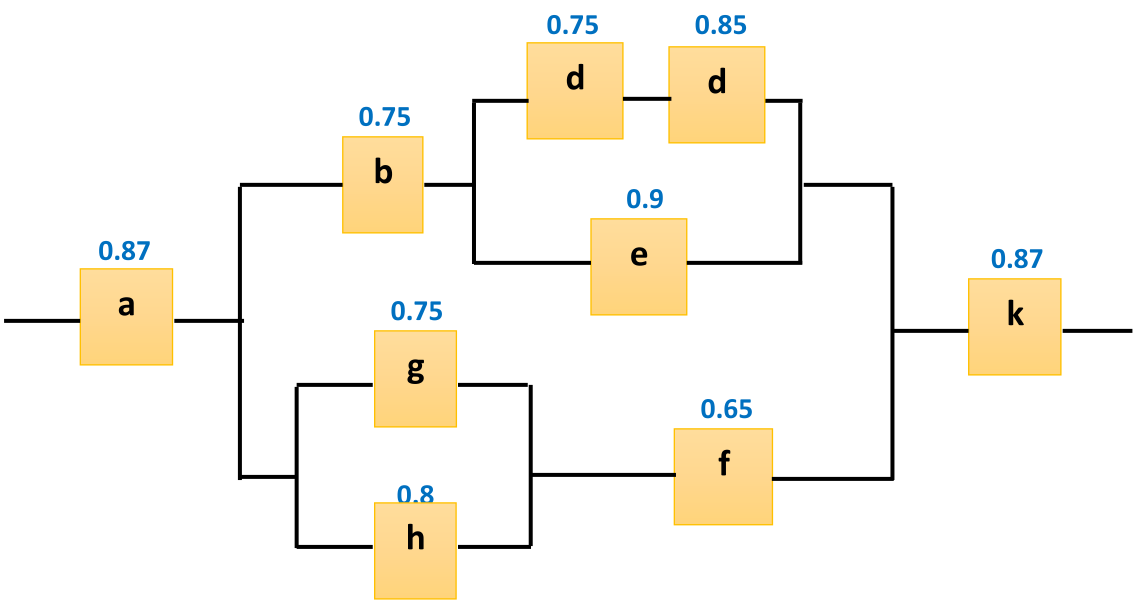


Figure (3.5) Example of mixed system

Solution:-

This method involves replacing each parallel path systematically with an identical on Single path, and the structure is gradually reduced to one consisting only of component. In this section, will try to find the reliability function of mixed system Fig. (3.2) as the within steps [10,11].

Step (1)

$$R_{cde} = 1 - [(1 - R_{cd})(1 - R_e)]$$

$$= 1 - [1 - R_e - R_{cd} + R_{cd}R_e]$$

$$= R_e + R_{cd} - R_{cd}R_e$$

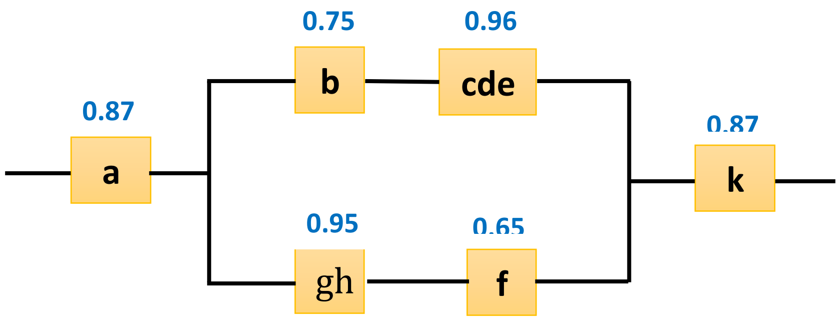
$$= 0.9 + 0.64 - 0.58 = \mathbf{0.96}$$

$$R_{gh} = 1 - \left[(1 - R_g)(1 - R_h)\right]$$

$$= 1 - \left[1 - R_h - R_g + R_gR_h\right]$$

$$= R_h + R_g - R_gR_h$$

$$= 0.8 + 0.75 - 0.6 = \mathbf{0.95}$$



Figure(3.6) step1

Step2

$$R_{bcde} = R_b \times R_{cde}$$

$$= 0.75 \times 0.96 = \mathbf{0.72}$$

$$R_{ghf} = R_{gh} \times R_f$$

$$= 0.95 \times 0.65 = \mathbf{0.62}$$

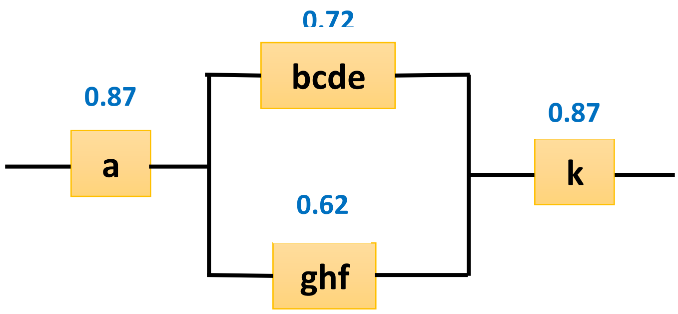


Figure (3.7) step2

Step3

$$R_{bcdeghf} = 1 - [(1 - R_{bcde})(1 - R_{ghf})]$$

$$= 1 - [1 - R_{ghf} - R_{bcde} + R_{bcde}R_{ghf}]$$

$$= R_{ghf} - R_{bcde} + R_{bcde}R_{ghf}$$

$$= 0.62 - 0.72 + 0.72 \times 0.62 = \mathbf{0.89}$$

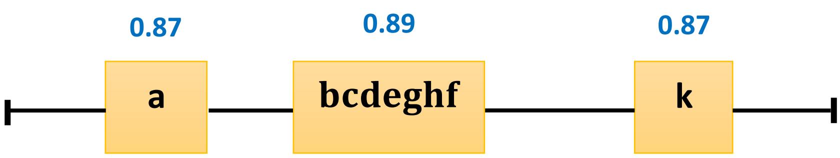


Figure (3.8) step3

Step4

$R_{system} = R_a \times R_{bcdeghf} \times R_k$

$= 0.87 \times 0.89 \times 0.87 = \mathbf{0.67}$

We will study the reliability allocation of this system in the following sections

3.2.2 Path – Tracing Method

This method considers any path from a source to a sink. Because of the system's performance, there must be at least one path from one end of the reliability block diagram to the others long as at least one route exists from start to finish, the device is operating.[6 ,13]

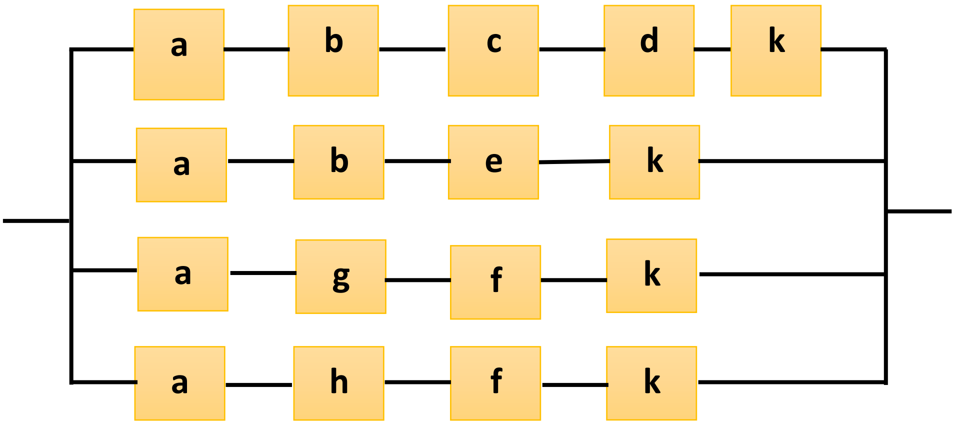


Figure (3.9) Modified mixed system

From Figure (3.9), the paths are

$P_1 = abcdk$

$P_2 = abek$

$P_3 = agfk$

$P_4 = ahfk$

$$P(P_1 \cup P_4 \cup P_3 \cup P_2)$$
$$= P(P_1) + P(P_4) + P(P_3) + P(P_2) - P(P_1 \cap P_4) - P(P_1 \cap P_3)$$
$$- P(P_1 \cap P_2) \ldots\ldots + P(P_1 \cap P_4 \cap P_3 \cap P_2) \quad (3.1)$$

$$R_S = R_aR_bR_cR_dR_k + R_aR_bR_eR_k + R_aR_gR_fR_k + R_aR_hR_fR_k - R_fR_gR_hR_k$$
$$- R_aR_bR_cR_dR_eR_k - R_aR_bR_eR_fR_gR_k - R_aR_bR_eR_fR_hR_k$$
$$- R_aR_bR_cR_dR_fR_gR_k - R_aR_bR_cR_dR_fR_hR_k + R_aR_bR_eR_fR_gR_hR_k$$
$$+ R_aR_bR_cR_dR_eR_fR_gR_k + R_aR_fR_cR_dR_eR_bR_hR_k$$
$$+ R_aR_bR_dR_cR_fR_gR_hR_k - R_aR_bR_cR_dR_hR_fR_gR_eR_k \quad (3.2)$$

Let $a = 0.87$, $b = 0.75$, $c = 0.75$, $d = 0.85$,

$e = 0.90$, $f = 0.65$, $g = 0.75$, $h = 0.8$, $k = 0.87$

$$\boldsymbol{R_S} = 0.51 + 0.37 + 0.39 + 0.36 - 0.296 - 0.33 - 0.25 - 0.199 - 0.1$$
$$- 0.19 + 0.199 + 0.16 + 0.17 + 0.14 - 0.17$$

$$= \mathbf{0.67}$$

3.3 System Reliability Allocation[13,25]

Reliability allocations for hardware or software systems will start immediately after the models for reliability have been developed .The initial values that are assigned to the systems hold be the values specified for reliability metrics for system , or a set of reliability related values that are more difficult to achieve than those specified. For the functionality aspect, the more aggressive reliability values are often allocated to the system than the required ones.

$$f(R_1, R_2, R_3, \dots R_n) \geq R \qquad (3.3)$$

where R is goal the reliability system and $RR1$,$RR2$,$RR3$,… ,$RRnn$ is the reliability goal of each component , and f has a relationship between reliability system and its component and obtained from the reliability analysis of the system to be allocated [26]. The allocation of reliability is important in the overall reliability program especially when components or vehicles are under development and complex. Among the advantages of reliability allocation, it is:[11 ,14 ,15]

1) Reliability allocations for hardware or software systems will starimmediately a fter the models for reliability have been developed.The initial values that are assi gned to the system should be the values specified for the reliability metricsof the system, or a set of reliabilityrelated values that are more difficult to achieve than those specified for the functionality aspect, the more aggressive reliability value sare often allocated to the system than the required ones.
2) The parties are responsible for improving their reliability through the use of reliability techniques better engineering designs high quality manufacturing processes and rigorous and accurate testing methods
3) Reliability allocations for hardware or software systems will start immediately after the models for reliability have been developed The initial values that are assigned to the system should be the values specified for the reliability metrics of the system, or a set of reliability related values that are more difficult to achieve than those specified. For the functionality aspect, the more aggressive reliability values are often allocated to the system than the required ones. [27,28]
4) It is possible that output reliability allocation as input to other reliability tasks.

3.4 Reliability Allocation Methods [1, 15]

There are many methods of allocating reliability and these methods vary in how much the subsystem dentition is available and the degree of accuracy required. In this section, we will look at the most common and used methods, such as

3.4.1 Equal Allocation Method

To achieve the overall system reliability objective, this method utilizes all standards for all system components and assigns a general reliability target for all components. In particular, the reliability results of the individual components in the early design stage framework are clear and useful. Thus, it is possible to write as

$$\prod_{i=1}^{n} R_i \geq R \qquad (3.4)$$

Or

$$R_i = \sqrt[3]{R} \quad , \quad for \quad i = 1,2,3, \dots , n. \qquad (3.5)$$

Where R is the required system reliability, R_i is the reliability requirement apportioned to subsystem i and each subsystem has the same reliability. If all components are exponential then.

$$\sum_{i=1}^{n} \lambda_i \geq \lambda \qquad (3.6)$$

Where is the maximum allowable failure rate to system

λi is the highest acceptable failure rate of component i. and

$$\lambda_i = \frac{\lambda}{n} \quad , \quad i = 1,2,3, \dots , n. \qquad (3.7)$$

My system can be reformulating as the following examples.

Example(3.2)

The vehicle (system) consists of an electrical sub-system, motor and a structure connected in a series the lifetime of all sub-system is distributed on the same amount of importance. If the system reliability goal is (0.98) in operation in (24) months, evaluate at this time the requirements of reliability and find the highest allowable failure rate of each sub-system.

Solution:-

$R_i = \sqrt[3]{R} \quad , \quad i = 1,2,3, \dots , n.$

Then

$R_i^* = R_{s5}^* = R_k^*$

$R^*(24) = \sqrt[3]{0.98} = 0.99$

$R^* = (0.99)(0.99)(0.99) = 0.97$

3.4.2 ARINC Approach Method

This method is based on a series of sub system with fixed failure rates so that the failure of any sub system causes the system to fail completely and that the task time of the component is equal to the time of the system task.it is assumed in this method that all components are Connected in a series and independent from each other and widely distributed and have a Common time in the test.[5,29,30]

In the reliability allocation we use the weighting factor as following Step

1) We find weighting factors (Wi) for individual components where

$$W_i = \frac{\lambda}{\sum_{i=1}^{n} \lambda_i} \quad , \quad i = 1,2,3,\dots,n \qquad (3.8)$$

Where (λi) is the failure rate of component i obtained from historical data or prediction. The factors the relative likelihood of failure. The larger the value of (i) , the more likely the component is to fail. The failure rate goal assigned to a variable should then be proportional to the size of the weight, namely the value of the weight.

2) find λ which the failure rate allocation to subsystem i depending on the $\lambda\lambda$which is the maximum allowable failure rate

Where

$$\lambda_i = W_i \,.\, \lambda \qquad (3.9)$$

and

$$\lambda = -\ln \frac{[R(t)]}{t} \qquad (3.10)$$

3) calculate the reliability

$$R_s = e^{-\lambda_i t} \qquad (3.11)$$

Example(3.2)

A computer consists of three sub- system having consecutive failure rates $\lambda 1$= 0.015 , $\lambda 2$ = 0.018 , $\lambda 3$ = 0.023 , failures per month, select the requirements of reliability through (36) mouths in service to achieve total reliability it is.(0.98)

Solution

By equation (3.6) we get

$$W_i = \frac{\lambda_i}{\sum_{i=1}^{n} \lambda_i} \quad , \quad i = 1,2,3,\dots,n$$

$$W_1 = \sum_{i=1}^{3} \lambda_i = \frac{0.015}{(0.015) + (0.018) + (0.023)} = \frac{0.015}{0.056} = 0.26$$

$$W_2 = \frac{0.018}{(0.015) + (0.018) + (0.023)} = \frac{0.018}{0.056} = 0.32$$

$$W_2 = \frac{0.023}{(0.015) + (0.018) + (0.023)} = \frac{0.023}{0.056} = 0.41$$

Now, by using equation (3.8) find λ where

$$\lambda = \frac{-\ln(0.98)}{36} = 5.612 \times 10^{-4}$$

$$\lambda_i = W_i \,.\, \lambda$$

$$\lambda_1 = 0.26 \times 5.612 \times 10^{-4} = 1.45912 \times 10^{-4}$$

$$\lambda_2 = 0.32 \times 5.612 \times 10^{-4} = 1.79584 \times 10^{-4}$$

$$\lambda_3 = 0.41 \times 5.612 \times 10^{-4} = 2.30091 \times 10^{-4}$$

Now, we find the reliability per component by using equation (3.9) we get

$$R1\ (36) = e(-1.0866 \times 10^{-4} \times 36) = 0.9989$$

$R2(36) = e(-1.79584 \times 10^{-4} \times 36) = 0.9868$

$R3(36) = e(-2.30092 \times 10^{-4} \times 36) = 0.9983$

Now the reliability at (36) months is

$R(36) = R1\ (36) \times R2\ (36) \times R3\ (36)$

$= (0.9989)(0.9868)(0.9983) = 0.98 \ \ reliability\ required$

3.5 Importance of Reliability

The importance of reliability, (IR) of component i in a system of n components is given by [5, 14]:

$$I_R(i) = \frac{\partial R_S}{\partial R_i} \qquad (3.12)$$

Where ∂ is the partial derivative, Ri is the component reliability and Rs is the system reliability. This equation's value for reliability importance is determined by both the component's reliability and its place in the system

Example(3.3)

We have a mixed system consisting of nine equipment's, we will try to find the importance of each unit of the system to know its importance in affecting the work of the system

$\boldsymbol{a = 0.87}$, $\boldsymbol{b = 0.75}$, $\boldsymbol{c = 0.75}$, $\boldsymbol{d = 0.85}$, $\boldsymbol{e = 0.90}$

$\boldsymbol{f = 0.65}$, $\boldsymbol{g = 0.75}$, $\boldsymbol{h = 0.8}$, $\boldsymbol{k = 0.87}$

Solution:

$$R_{System} = R_aR_bR_kR_e + R_aR_fR_kR_g + R_aR_kR_hR_f + R_aR_bR_dR_cR_k - R_aR_fR_kR_hR_g - R_aR_bR_cR_dR_eR_k - R_aR_bR_eR_fR_gR_k - R_aR_bR_eR_fR_hR_k - R_aR_bR_cR_dR_fR_gR_k - R_aR_bR_cR_dR_fR_hR_k + R_aR_bR_eR_fR_gR_hR_k + R_aR_bR_cR_dR_eR_fR_gR_k + R_aR_bR_cR_dR_eR_fR_hR_k + R_aR_bR_cR_dR_fR_gR_hR_k - R_aR_bR_cR_dR_eR_fR_gR_hR_k$$

$$\frac{\partial R_S}{\partial R_a} = R_bR_kR_e + R_fR_kR_g + R_kR_hR_f + R_bR_dR_cR_k - R_fR_kR_hR_g - R_bR_cR_dR_eR_k - R_bR_eR_fR_gR_k - R_bR_eR_fR_hR_k - R_bR_cR_dR_fR_gR_k - R_bR_cR_dR_fR_hR_k + R_bR_eR_fR_gR_hR_k + R_bR_cR_dR_eR_fR_gR_k + R_bR_cR_dR_eR_fR_hR_k + R_bR_cR_dR_fR_gR_hR_k - R_bR_cR_dR_eR_fR_gR_hR_k$$

$$\frac{\partial R_S}{\partial R_a} = 0.59 + 0.42 + 0.45 + 0.42 - 0.34 - 0.37 - 0.29 - 0.23 - 0.2 - 0.2 + 0.23 + 0.18 + 0.19 + 0.16 - 0.15 = \mathbf{0.7778}$$

$$\frac{\partial R_S}{\partial R_b} = R_aR_kR_e + R_aR_dR_cR_k - R_aR_cR_dR_eR_k - R_aR_eR_fR_gR_k - R_aR_eR_fR_hR_k - R_aR_cR_dR_fR_gR_k - R_aR_cR_dR_fR_hR_k + R_aR_eR_fR_gR_hR_k + R_aR_cR_dR_eR_fR_gR_k + R_aR_cR_dR_eR_fR_hR_k + R_aR_cR_dR_fR_gR_hR_k - R_aR_cR_dR_eR_fR_gR_hR_k$$

$$\frac{\partial R_S}{\partial R_b} = 0.68 + 0.48 - 0.43 - 0.33 - 0.27 - 0.24 - 0.25 + 0.27 + 0.21 + 0.23 + 0.19 - 0.17 = \mathbf{0.2790}$$

$$\frac{\partial R_S}{\partial R_c} = R_aR_bR_dR_k - R_aR_bR_dR_eR_k - R_aR_bR_cR_dR_fR_gR_k - R_aR_bR_dR_fR_hR_k + R_aR_bR_dR_eR_fR_gR_k + R_aR_bR_dR_eR_fR_hR_k + R_aR_bR_dR_fR_gR_hR_k - R_aR_bR_dR_eR_fR_gR_hR_k$$

$$\frac{\partial R_S}{\partial R_c} = 0.48 - 0.43 - 0.28 - 0.25 + 0.21 + 0.23 + 0.19 - 0.17 = \mathbf{0.0185}$$

$$\frac{\partial R_S}{\partial R_d} = R_aR_bR_cR_k - R_aR_bR_cR_eR_k - R_aR_bR_cR_fR_gR_k - R_aR_bR_cR_fR_hR_k + R_aR_bR_cR_eR_fR_gR_k + R_aR_bR_cR_eR_fR_hR_k - R_aR_bR_cR_eR_fR_gR_hR_k$$

$$\frac{\partial R_S}{\partial R_d} = 0.41 - 0.38 - 0.21 - 0.22 + 0.19 + 0.199 + 0.17 - 0.15 = \mathbf{0.0163}$$

$$\frac{\partial R_S}{\partial R_e} = R_aR_bR_k - R_aR_bR_cR_dR_k - R_aR_bR_fR_gR_k - R_aR_bR_fR_hR_k + R_aR_bR_fR_gR_hR_k + R_aR_bR_cR_dR_fR_gR_k + R_aR_bR_cR_dR_fR_hR_k - R_aR_bR_cR_dR_fR_gR_hR_k$$

$$\frac{\partial R_S}{\partial R_e} = 0.57 - 0.36 - 0.28 - 0.295 + 0.22 + 0.18 + 0.19 - 0.14 = \mathbf{0.0787}$$

$$\frac{\partial R_S}{\partial R_f} = R_aR_kR_g + R_aR_kR_h - R_aR_kR_hR_g - R_aR_bR_eR_gR_k - R_aR_bR_eR_hR_k - R_aR_bR_cR_dR_gR_k - R_aR_bR_cR_dR_hR_k + R_aR_bR_eR_gR_hR_k + R_aR_bR_cR_dR_eR_gR_k + R_aR_bR_cR_dR_eR_hR_k + R_aR_bR_cR_dR_gR_hR_k - R_aR_bR_cR_dR_eR_gR_hR_k$$

$$\frac{\partial R_S}{\partial R_f} = 0.57 + 0.61 - 0.45 - 0.38 - 0.41 - 0.27 - 0.29 + 0.31 + 0.24 + 0.26 + 0.22 - 0.195 = \mathbf{0.1993}$$

$$\frac{\partial R_S}{\partial R_g} = R_aR_fR_k - R_aR_fR_kR_h - R_aR_bR_eR_fR_k - R_aR_bR_cR_dR_fR_k + R_aR_bR_eR_fR_hR_k + R_aR_bR_cR_dR_eR_fR_k + R_aR_bR_cR_dR_fR_hR_k - R_aR_bR_cR_dR_eR_fR_hR_k$$

$$\frac{\partial R_S}{\partial R_g} = 0.49 - 0.39 - 0.33 - 0.24 + 0.27 + 0.21 + 0.19 - 0.17 = \mathbf{0.0273}$$

$$\frac{\partial R_S}{\partial R_h} = +R_aR_kR_f - R_aR_fR_kR_g - R_aR_bR_eR_fR_k - R_aR_bR_cR_dR_fR_k + R_aR_bR_eR_fR_gR_k + R_aR_bR_cR_dR_eR_fR_k + R_aR_bR_cR_dR_fR_gR_k - R_aR_bR_cR_dR_eR_fR_gR_k$$

$$\frac{\partial R_S}{\partial R_h} = 0.49 - 0.37 - 0.33 - 0.24 + 0.25 + 0.21 + 0.18 - 0.16 = \mathbf{0.0341}$$

$$\frac{\partial R_S}{\partial R_k} = R_aR_bR_e + R_aR_fR_g + R_aR_hR_f + R_aR_bR_dR_c - R_aR_fR_hR_g - R_aR_bR_cR_dR_e - R_aR_bR_eR_fR_g - R_aR_bR_eR_fR_h - R_aR_bR_cR_dR_fR_g - R_aR_bR_cR_dR_fR_h + R_aR_bR_eR_fR_gR_h + R_aR_bR_cR_dR_eR_fR_g + R_aR_bR_cR_dR_eR_fR_h + R_aR_bR_cR_dR_fR_gR_h - R_aR_bR_cR_dR_eR_fR_gR_h$$

$$\frac{\partial R_S}{\partial R_k} = 0.59 + 0.42 + 0.45 + 0.42 - 0.34 - 0.37 - 0.29 - 0.31 - 0.20 - 0.22 + 0.23 + 0.18 + 0.18 + 0.16 - 0.15 = \mathbf{0.7778}$$

Chapter Four

Conclusions

and

Future Work

4-1 Conclusions

This research has shown that the mixed system can be transformed to the series system by using reduction technique, and this process allowed to us study the reliability allocation in order to increase the reliability of given mixed system. Although two methods have been introduced in order to evaluate the assignment of reliability and select the best one which is to help in increasing the reliability of the given system, we noticed that the ARINC Approach method is the best of Equal Allocation Technique because the first one is more accurate . We were able to explain the significance of each system unit and the degree of its effect on the overall activity of the mixed system , as well as the fact that duplicating the critical units improves system reliability, which is an essential aim for all engineering industries.

4.2 Future Works

It is hoped that future studies of in mathematics will study the following:

1- Solving the problems of reliability allocation without using the approximation $R(t) = 1 - \lambda t$.

2-Studying the optimal allocation since reliability allocation should be accomplished in least –cost manner.

3- Making use of the generalization lagrangian multiplier technique.

4- Adding new methods for calculating fuzzy reliability allocation.

5- Presenting practical application for reliability allocation.

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المستخلص

في هذا البحث، نختبر تعيين الموثوقية للأنظمة المختلطة باستخدام تقليل عملية الوحدة المتسلسلة ، مم يسمح بتبسيط هذه الأنظمة إلى حساب أبسط لنظام السلسلة. كما قدمنا تقنيتين من أجل معالجة تخصيص الموثوقية للنظام المختلط وأيضًا ، سننظر في أهمية كل وحدة في نظام مختلط ونحاول تقدير تأثيرها على الأداء العام للنظام اعتمادًا على أهميتها. سنشرح أيضا كيفية استخدام تقنية إضافة لتعزيز كفاءة الوحدات التي لها تأثير أكبر على الأداء العام للنظام أكثر من غيرها.

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قسم الرياضيات

بعض التقنيات لزيادة موثوقية الانظمة

بحث مقدم الى مجلس كلية التربية للعلوم الصرفة – جامعة بابل
كجزء من متطلبات نيل شهادة الدبلوم العالي تربية / الرياضيات

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