Increase the Reliability of Critical Units by Using Redundant Technologies

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Abstract: In this article, 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.

1. Introduction

The term reliability can be traced back to 1816, and the poet Samuel Taylor Coleridge was rest attested [1, 2]. Before World War II, The concept was first used to describe consistency. A research (in any area of science) was deemed accurate if the same findings were obtained per time. In the 1920s, Bell Labs' Walter A. Shewhart was encouraging product optimization through the use of statistical process management, at the same time Faludi Weibull was working on statistical models for fatigue [3]. The concept of reliability developed after Second World War. Since there is no other branch of engineering science has developed and advanced as fast as reliability engineering with the exception of computer technology and environmental engineering. Complex system theory plays a significant part in many studies, beginning with computer science, physics and engineering, atomic and populace science, and so on [4]. In these ends, technological advancement has led in the creation of a huge range of complicated and automated systems. Many of these instruments are costly and increasingly reliable [5]. There is an increasing demand for these systems to be extremely reliable, particularly in ends where replacement expenses (such as storage and underwater) are prohibitive. Most systems may fail randomly [6]. If this failure causes enhanced expenses, impacts equipment e activeness, and creates inconvenience and risk to public safety, the user is needed to guarantee that the equipment he uses is reliable and e active. Brands in specie require the use of high-precision instruments on the market. That's why reliability is a main factor in any engineering design [7, 8]. We are addressing reliability redundancy models of mixed system in this article. the aim of this redundancy is to achieve the systems reliability objective, models of reliability of mixed are developed and techniques are presented in this paper to solve the problem.

2. Basic definitions and concepts

Definition (2.1) System [8]
A group of regularly ordered compounds that communicate in order to perform With each other and with external components or other structures given purpose.

Definition (2.2) Reliability [9]
The probability that for a certain period of time the system will survive is established. It can be expressed as the time to system failure in terms of random variable T.

\[ R(t) = p\{T > t\} \]

(2.1)

Or \[ R(t) = 1 - F(t) = \int_0^t f(t)\,dt \]

**Definition (2.4) series system** [9, 10]

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

![Series System Diagram](image1)

**Figure (2.1) Series system**

The reliability of the system is given by

\[ R_s = R_{s1} \times R_{s2} \times R_{s3} \times \ldots \times R_{sn} \]

\[ = \prod_{i=1}^{n} R_{si} \]  

(2.2)

3. **Mixed system**

This system is a combination of both parallel and series systems and we only break the system into a series and parallel to find each subsystem’s reliability in order to find the system’s reliability [11, 12].

![Mixed System Diagram](image2)

**Figure (2.2): Mixed system**

3.1 **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 (2.3): Modified mixed system

From Figure (2.3), the paths are

\[ P_1 = a \ b \ c \ d \ k \]
\[ P_2 = a \ b \ e \ k \]
\[ P_3 = a \ g \ f \ k \]
\[ P_4 = a \ h \ f \ k \]

\[
P(\bigcup P_1 \cup P_2 \cup P_3 \cup P_2) = P(P_1) + P(P_4) + P(P_3) - P(P_1 \cap P_4) - P(P_1 \cap P_3) - (2.3)
\]

\[
\cdots + P(P_1 \cap P_2) \]

\[
R_{\text{system}} = R_a R_b R_c R_d R_e R_k + R_a R_b R_e R_k + R_a R_d R_g R_k + R_a R_h R_f R_k - R_a R_f R_g R_h R_k
\]

\[
- R_a R_b R_c R_d R_e R_k - R_a R_b R_e R_f R_h R_k - R_a R_b R_e R_f R_g R_k - R_a R_b R_e R_g R_h R_k
\]

\[
- R_a R_b R_c R_d R_f R_h R_k + R_a R_b R_c R_f R_g R_h R_k + R_a R_b R_c R_d R_f R_g R_k
\]

\[
+ R_a R_f R_c R_d R_e R_h R_k + R_a R_b R_c R_e R_f R_g R_h R_k - R_a R_b R_c R_f R_g R_h R_k. (2.4)
\]

Let \[ a = 0.87, b = 0.75, c = 0.75, d = 0.85, e = 0.90, f = 0.65, g = 0.75, h = 0.8, k = 0.87 \]

Then

\[
R_{\text{system}} = 0.51 + 0.37 + 0.39 + 0.36 - 0.296 - 0.33 - 0.25 - 0.199 - 0.18 - 0.19
\]
3.2 Importance of Reliability

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

\[
I_R(i) = \frac{\partial R_s}{\partial R_i}
\]

Where \(\partial\) is the partial derivative, \(R_i\) is the component reliability and \(R_s\) 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 (1)

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,

\[a = 0.87, b = 0.75, c = 0.75, d = 0.85, e = 0.90, f = 0.65, g = 0.75, h = 0.8, k = 0.87.\]

Solution:

\[
R_{system} = R_a R_b R_c R_e R_f R_g + R_a R_f R_k R_g + R_a R_k R_h R_f + R_a R_b R_d R_c R_k - R_a R_f R_k R_h R_g
\]

\[-R_a R_b R_c R_d R_e R_k - R_a R_b R_e R_f R_g R_k - R_a R_b R_g R_f R_h R_k - R_a R_b R_c R_d R_f R_g R_k\]

\[-R_a R_b R_c R_d R_f R_h R_k + R_a R_b R_c R_d R_f R_g R_k + R_a R_b R_c R_d R_e R_f R_g R_k\]

\[+R_a R_b R_c R_d R_e R_f R_g R_k - R_a R_b R_c R_d R_e R_f R_g R_k\]

\[
\frac{\partial R_s}{\partial R_a} = R_b R_c R_e + R_k R_g R_f + R_f R_h R_k + R_b R_k R_c R_d - R_g R_f R_h R_k - R_b R_e R_d R_c R_k - R_a R_g R_f R_e R_k
\]

\[-R_b R_e R_h R_g R_f R_k - R_b R_c R_d R_f R_g R_k - R_b R_d R_c R_f R_h R_k + R_b R_e R_f R_g R_h R_k\]

\[+R_b R_e R_d R_e R_f R_g R_k\]

\[
\frac{\partial R_s}{\partial R_a} = 0.59 + 0.42 + 0.45 + 0.42 - 0.34 - 0.37 - 0.29 - 0.23 - 0.20 - 0.22 + 0.23 + 0.18 + 0.19 + 0.16 - 0.15 = 0.7778
\]

\[
\frac{\partial R_s}{\partial R_b} = R_a R_c R_d R_e R_k - R_a R_k R_d R_e R_c - R_a R_e R_g R_f R_k - R_e R_a R_f R_g R_h R_k
\]

\[-R_a R_c R_d R_f R_g R_f - R_a R_c R_d R_f R_h R_k + R_a R_e R_f R_g R_h R_k + R_a R_e R_d R_c R_f R_g R_k\]

\[+R_a R_c R_d R_e R_f R_h R_k + R_a R_c R_d R_f R_g R_h R_k - R_a R_c R_d R_e R_f R_g R_h R_k\]

\[
\frac{\partial R_s}{\partial R_b} = 0.68 + 0.48 - 0.43 - 0.33 - 0.27 - 0.24 - 0.25 + 0.27 + 0.21 + 0.23 + 0.19 - 0.17
\]
\[
\frac{\partial R_s}{\partial R_c} = 0.48 - 0.43 - 0.28 - 0.25 + 0.21 + 0.23 + 0.19 - 0.17 = 0.0185
\]
\[
\frac{\partial R_s}{\partial R_d} = 0.41 - 0.38 - 0.21 - 0.22 + 0.19 + 0.199 + 0.17 - 0.15 = 0.0163
\]
\[
\frac{\partial R_s}{\partial R_e} = 0.57 - 0.36 - 0.28 - 0.295 + 0.22 + 0.18 + 0.19 - 0.14 = 0.0787
\]
\[
\frac{\partial R_s}{\partial R_f} = 0.57 + 0.61 - 0.45 - 0.38 - 0.41 - 0.27 - 0.29 + 0.31 + 0.24 + 0.26 + 0.22 - 0.195
\]
\[
= 0.1993
\]
\[
\frac{\partial R_s}{\partial R_g} = 0.49 - 0.39 - 0.33 - 0.24 + 0.27 + 0.21 + 0.19 - 0.17 = 0.0273
\]
\[
\frac{\partial R_s}{\partial R_h} = 0.49 - 0.37 - 0.33 - 0.24 + 0.25 + 0.21 + 0.18 - 0.16 = 0.0341
\]
4. Redundancy

If manufacturing highly durable components is either impractical or prohibitively expensive, we can increase system efficiency by adding redundancies, which entails the deliberate creation of new parallel paths in a system. We discovered that combining two components with different output probabilities yields the same outcome [7,15].

\[
P(a) \text{ or } P(b)
\]

Assuming that every item is self-contained. Since \(P(a)\) and \(P(b)\) can never be greater than one, their product can never be greater than \(P(a)\) or \(P(b)\). As a result, \(P(a \text{ or } b)\) is always greater than \(P(a) \text{ or } P(b)\) (b). This shows a simple method of increasing system reliability if the element's reliability cannot be improved. Whether or not one or more of the elements are needed [16, 17].

5. Element Redundancy

Let \(R_a\) and \(R_b\) are the reliabilities of unit \(a\) and \(b\) respectively; both are connected in parallel. If the device will work with either \(a\) or \(b\), the system's reliability is \(R_a + R_b - R_a \times R_b\) which is superior to element \(a\) and \(b\)'s individual reliabilities [18, 19].

\[
\frac{\partial R_s}{\partial R_k} = R_a R_e R_b + R_g R_f R_a + R_a R_f R_h + R_a R_b R_c R_d - R_a R_f R_g R_h - R_a R_b R_c R_d R_e
\]

\[
-R_a R_f R_e R_b R_g - R_a R_b R_f R_e R_h - R_a R_c R_d R_b R_f R_g - R_a R_f R_c R_b R_d R_h + R_e R_b R_a R_f R_g R_h
\]

\[
+R_a R_d R_c R_e R_f R_b R_g + R_a R_c R_b R_a R_d R_h R_f R_e + R_a R_b R_d R_f R_c R_h R_g - R_a R_e R_c R_b R_d R_f R_g R_h
\]

\[
\frac{\partial R_s}{\partial R_k} = 0.59 + 0.42 + 0.45 + 0.42 - 0.34 - 0.37 - 0.29 - 0.31 - 0.20 - 0.22 + 0.23 + 0.18
\]

\[
+0.18 + 0.16 - 0.15 = 0.7778
\]

Example (2) Now, going back to the previous illustration, we will introduce the technique of adding (redundancy) to the mixed system depending on the importance of each unit and the extent of its impact on the operation of the system.

By applying the importance technique, we note that the component \(a\) and component \(k\) had the highest value of importance. Based on that, we duplicate the components \(a\) by \(x\) and \(k\) by \(y\) respectively, as shown by figure (2.5), \(a = x = 0.87\), \(k = y = 0.87\).
Now we will recalculate the reliability of the system after duplicating the components a and k to see the effect of adding new units (x and y) to the system. To do this, and for simplicity, we will apply the reduction method to calculate mixed system reliability, as follows [6, 20],

**Step1:**

\[ S_1 = 1 - (1 - 0.87)(1 - 0.87) \]
\[ = 1 - (0.13)(0.13) = 0.98 \]

\[ S_2 = 1 - [1 - (0.75)(0.85)(1 - 0.90)] \]
\[ = 1 - 0.036 = 0.96 \]

\[ S_3 = 1 - (1 - 0.75)(1 - 0.8) \]
\[ = 1 - (0.25)(0.2) \]
\[ = 0.95 \]

\[ S_4 = 1 - [(1 - 0.87)(1 - 0.87)] \]
\[ = 1 - 0.02 = 0.98 \]

**step2:**

![Diagram](image-url)
Step3:

\[ S_5 = (0.75)(0.96) = 0.72 \]
\[ S_6 = (0.95)(0.65) = 0.62 \]

![Figure (2.7): step 3](image)

Step4:

\[ S_6 = 1 - (1 - 0.72)(1 - 0.62) \]
\[ = 1 - (0.28)(0.38) = 1 - 0.11 = 0.89 \]

![Figure (2.8): step 4](image)

\[ R_{system} = 0.98 \times 0.89 \times 0.98 = 0.85. \]

By comparing this result with the equation (2.4), we note that there is a significant increase in the reliability of the mixed system.

**Conclusions**

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 in this article, as well as the fact that duplicating the critical units improves system reliability, which is an essential aim for all engineering industries.

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