Using Some Techniques To Increase System Reliability

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Abstract:

In this research we shall briefly discuss some techniques that can be used for increasing system reliability . A large number of reliability studies have brought out the obvious fact that many failures can be attributed to improper design and over stressing of components. As such , it would be justifiable to use some of more powerful techniques of analysis only after taking suitable precautions about these simple but often effective matters.

المستخلص

تناول هذا البحث بعض التقنيات التي تساعد على زيادة وثوقية الأنظمة المختلفة وقد احتوى البحث على طريقتين لزيادة ثقة الأنظمة وهي **الإضافة (وتضمنت هذه الطريقة إضافة مركبة و إضافة وحدة)** والطريقة الأخرى هي **تحديد أهمية ثقة المكونة** (المركّبة).

1.Introduction

As first approach to improving reliability , we can use superior components and parts with low failure rates .However , we would immediately realize that components of high reliability will require more time and more money for development. They may also be larger in size and weight .generally , the objective is not merely to produce a system with the highest reliability , but to evolve a system which reflects an optimum cost (The cost of improving reliability is not considered in this research).

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2. Redundancy [1]

If the state of art is such that either it is not possible to produce highly reliable components or the cost of producing such components is very high , we can improve the system reliability by the technique of introducing redundancies . this involves the deliberate creation of new parallel paths in a system . we have observed that if two elements with probabilities of success P(a) and P(b) are connected in parallel , the probability P(a or b) is

$$P(a \text{ or } b) = P(a) + P(b) - P(a \text{ and } b)$$
$$= P(a) + P(b) - P(a) \times P(b)$$

assuming that the elements are independent . Since both P(a) and P(b) are individually less than one , their product is always less than P(a) or P(b) . Hence , P(a or b) is always greater than either P(a) or P(b).

this illustrates a simple method of improving the reliability of a system when the element reliability cannot be increased . Although either one of the elements is sufficient for the successful operation of the system , we deliberately use both elements so as to increase the probability of success , thus causing the system to become redundant, There are many methods of introducing redundancies in a system ; a few of these will be considered in this research .

2.1 Element Redundancy

Let a_1 be an element whose reliability is $R_1(a)$. Another element a_2 , with reliability $R_2(a)$, is connected to it in parallel as shown in fig (1) .

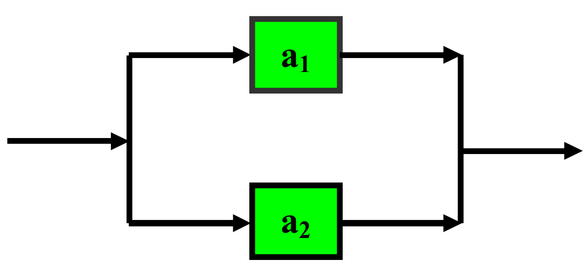


Fig (1)

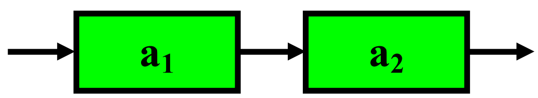
if the system can operate with either a_1 or a_2 , then as the reliability of the system is R (a_1) + R (a_2) - R (a_1)× R (a_2) , which is better than the individual reliabilities of elements a_1 and a_2 .

2.2 Unit Redundancy [2]

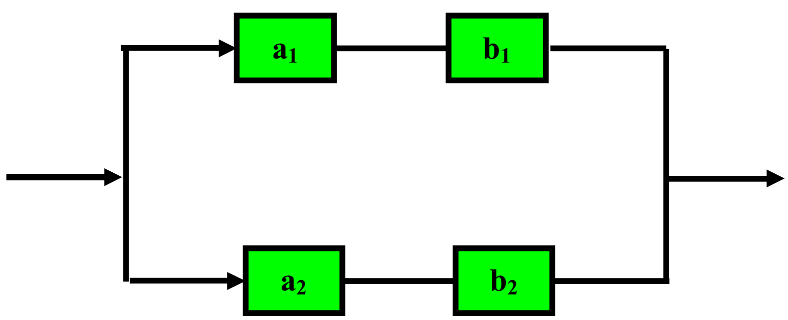
Let two elements a_1 and b_1 , with reliabilities $P(a_1)$ and $P(b_1)$, respectively , be connected in series as shown in fig (a) . The probability of successful operation of the system is $P(S) = P(a_1 \text{ and } b_1)$

$$= P(a_1 \times b_1) \qquad \ldots(1)$$

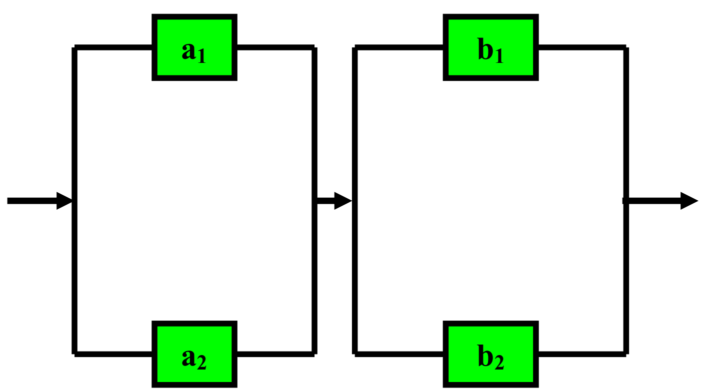
assuming that the two elements are independent . next , we introduce redundancies in the form shown in fig (b),



(a)



(b)



(c)

Figure (2)

so that the path with elements a_1 and b_1 in series in duplicated by another path with elements a_2 and b_2 in series . the successful operation of the system depends on the successful functioning of path a_1b_1 paths a_2b_2 . Hence, the probability of successful operation of the system is given by

$P(S)= P[(a_1 \text{ and } b_1) \text{ or } (a_2 \text{ and } b_2)]$

$\quad = P(a_1 \text{ and } b_1) + (a_2 \text{ and } b_2) - P[(a_1 \text{ and } b_1) \text{ and } (a_2 \text{ and } b_2)]$

$\quad = P(a_1) \times P(b_1) + P(a_2) \times P(b_2) - P(a_1) \times P(b_1) \times P(a_2) \times P(b_2) \qquad \ldots(2)$

we can also consider the alternative shown in fig (c). the reliability in this case is given by

$P(S) = P[(a_1 \text{ or } a_2) \text{ and } (b_1 \text{ or } b_2)]$

$\quad = P(a_1 \text{ or } a_2) \times P(b_1 \text{ or } b_2)$

$\quad = [P(a_1) + P(a_2) - P(a_1) \times P(a_2)]\,[P(b_1) + P(b_2) - P(b_1) \times P(b_2)] \qquad \ldots(3)$

To compare these reliabilities , let the elements be identical , each of reliability p . From Eqs. (1), (2) and (3) we get

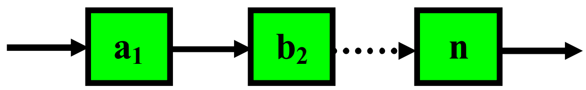
$$
\begin{aligned}
&P_a(S)= p^2 && \text{for fig.(2-a)},\\
&P_b(S)= 2p^2 - p^4 = p^2(2- p^2)\,, && \text{for fig.(2-b)}, \qquad \ldots(4)\\
&P_c(S)=(2p - p^2)(2p- p^2) = p^2(2- p)^2\,, && \text{for fig.(2-c)}
\end{aligned}
$$

Since p is less than one , $(2- p^2)$ is greater than one . hence $P_b(S)$ as given by eq. (4) is greater than $P_a(S)$. Further , we can easily show that $P_c(S)$ is greater than $P_b(S)$ since

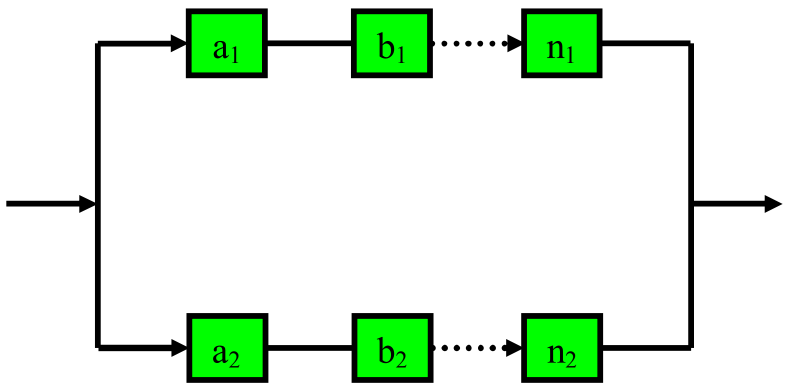
$$
\frac{P_C(S)}{P_b(S)} = \frac{(2-p)^2}{2-p^2} = \frac{4-4p+p^2}{2-p^2}
$$

$$
= 1 + 2\frac{(2-p)^2}{2-p^2},
$$

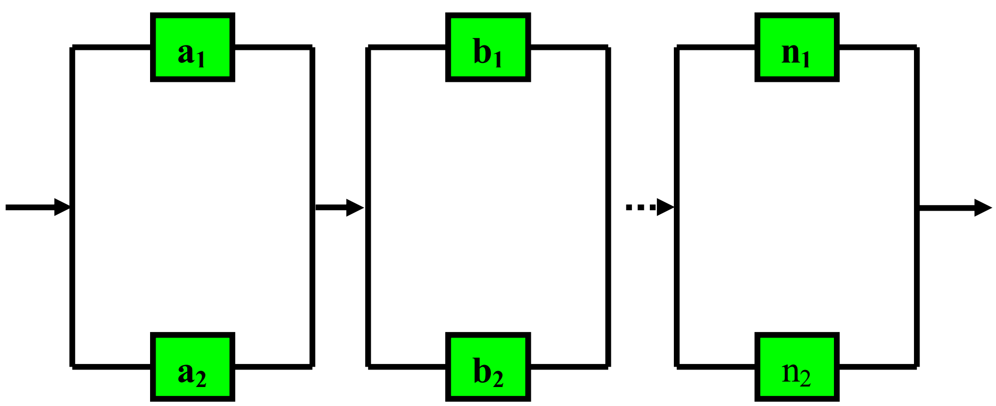
and this quantity is greater than one .Hence , the system shown in fig. (2-c) has the greatest reliability . the difference between fig (2-b) and (2-c) lies in the manner in which the redundancy is introduced. In fig.(2-b) , there is a redundancy in unit (a_1 and b_1) or (a_2 and b_2) . in fig.(2-c) , on the other hand , there is a component redundancy or element redundancy of the from (a_1 or a_2) and (b_1 or b_2) . Therefore , an element redundancy is always superior to unit redundancy . this is also true for n elements as shown in fig.(3) . The system shown in fig.(3-c) is most reliable of the three combinations. Even if the elements are not identical , element or component redundancy is superior to unit redundancy as illustrated by example (1)



(a)



(b)



(c)
Figure (3)

Example (1) : Consider two elements a and b with reliabilities 0.7 and 0.8, respectively , to be connected in series as shown in fig.(2-a) .

If redundancies are introduced in the form shown in fig 2-b and 2-c , what are the resultant system reliabilities?

Solution

For series configuration with no redundancy as shown in fig.2-a,

$P(S)=P(a) \times P(b) =0.7 \times 0.8 = 0.56$.

For unit redundancy of the type shown in fig. 2-b, the system reliability from eq.(2) is

$P(S) = P(a_1) \times P(b_1) + P(a_2) \times P(b_2) - P(a_1) \times P(b_1) \times P(a_2) \times P(b_2)$

$= 2(0.7)(0.8)-(0.7)^2(0.8)^2 =0.608$

for element redundancy of the type shown in fig.(2-c), the system reliability from eq.(3) is

$P(S) = (0.7 + 0.7 – (0.7)^2) (0.8 + 0.8 – (0.8)^2) = (0.91)(0.96) = 0.874$

3. Component Reliability Importance [3] , [5]

The component importance measure is an index of how much or how little an individual component contributes to the overall system reliability. It is useful to obtain the reliability importance value of each component in the system prior to investing resources toward improving specific components. This is done to determine where to focus resources in order to achieve the most benefit from the improvement effort. The reliability importance of a component can be determined based on the failure characteristics of the component and its corresponding position in the system.

Once the reliability of a system has been determined, engineers are often faced with the task of identifying the least reliable components in the system in order to improve the design. For example, in a series system, the least reliable component has the biggest effect on the system reliability. If the reliability of the system needs to be improved, then efforts should first be concentrated on improving the reliability of the component that has the largest effect on reliability In simple systems such as a series system, it is easy to identify the weak components. However, this becomes more difficult in more complex systems. Therefore, a mathematical approach is needed to provide the means of identifying and quantifying the importance of each component in the system.

4. Calculating Reliability Importance [4] , [6]

The reliability importance, *I*, of component *i* in a system of *n* components is given by:

$$I(i) = \frac{\partial R_S(t)}{\partial R_i(t)} \qquad \ldots(5)$$

where

$R_S(t)$ is the system reliability , $R_i(t)$ is the component reliability and ∂ is the partial derivative.

The value of the reliability importance given by this equation depends both on the reliability of a component and its corresponding position in the system.

Example (2): Consider a series system of three components, with reliabilities of 0.7, 0.8, and 0.9 at a given time, *t*. Using Eqn. (5), the reliability importance in terms of a value for each component can be obtained.

Solution :The values shown for each component were obtained using Eqn. (5). The reliability equation for this series system is given by:

$$R_S(t) = R_1(t).R_2(t).R_3(t) \qquad \ldots(6)$$

Taking the partial derivative of Eqn. (6) with respect to R_1 yields:

$$I(1) = \frac{\partial R_S(t)}{\partial R_i(t)} = 0.8 * 0.9 = 0.72$$

Thus the reliability importance of Component 1 is 0.72. The reliability importance values for Components 2 and 3 are obtained in a similar manner.

5. Conclusion

1. A parallel configuration can greatly increase system reliability.

2. Better reliability can be obtained by element or component redundancy than by unit redundancy.
3. Using reliability importance measures is one method of identifying the relative importance of each component in a system with respect to the overall reliability of the system.

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