Reliability Allocation in Parallel – Series Systems

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Abstract:

In this paper we evaluate the reliability allocation in parallel - series systems by using **reduction to series element method** which it helping to reduced these systems and complex systems to series systems easier computing .

المستخلص

في هذا البحث تم دراسة مشكلة تخصيص الثقة للأنظمة " المتوازية – المتسلسلة " وقد تم استخدام **طريقة اختزال العناصر** وذلك بتحويل النظام المعقد إلى نظام متسلسل فقط ، لتساعد في حساب مشكلة تخصيص الثقة لهذا نوع من الأنظمة.

1. Introduction

Many researchers works to compute the reliability allocation in series, and complex systems like Srinath (1985) , Subrie (1996) and Jorge (2004).

The reliability factor of a system is known or is specified on the basis of the overall mission requirements. If the system comprises many elements and units, we must have method to determine the reliability factor for each of them . So that when they are assembled to form a system . The system reliability will have the desired value.

The purpose of reliability allocation is to establish a goal or objective for the reliability of each component so that the manufacturers can have an idea of the performance required of this product.

2. Some definitions and general concepts

The terminology to follow is very important in creating and analyzing reliability block diagrams.

Definition (1-2) Reliability System R_S or R_{System}

The probability that an item will perform its intended function for a specified interval under stated conditions . see (Govil)

Definition (2-2) Reliability Allocation

The process by which the failure allowance for a system is allocated in some logical manner its sub-systems and elements. see (Srinath)

3. Problem description

If (m) such sets are connected in series where each set consists of (n) component in parallel , then the reliability of the system (R_{System} or R_S) is given by

$$R_{system} = \left[1-(1-R)^n\right]^m \qquad \ldots(1)$$

$$R_{system} = \left[R_P\right]^m \quad where\; R_P = 1-(1-R)^n$$

The parallel – series configuration is depicted in fig (1)

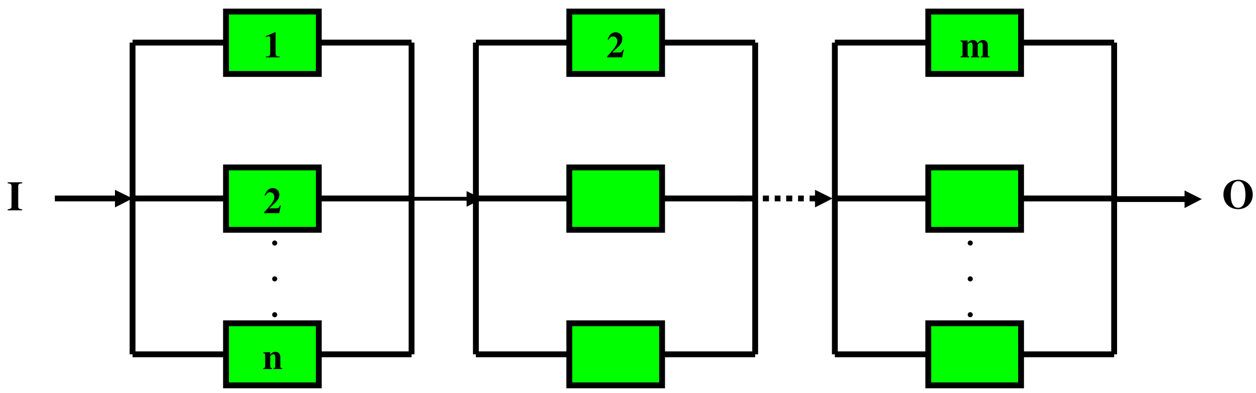

Fig (1) parallel – series system

For calculating the reliability allocation, the given system convert into an equivalent system consisting of only series components. This process is termed reduction to series element method ,in this method we systematically replace each parallel path by an equivalent single path and ultimately reduce the given system to one consisting of only series elements as in fig.(2) (the exponential distribution is useful model in this work).

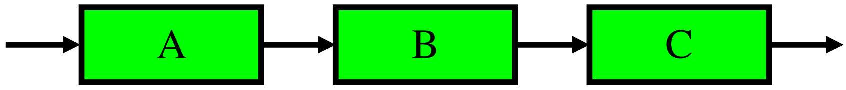

Fig.(2) Series system

The principle adopted in this method for subdividing the system failure allowance is that the failure allowance of each component is directly proportional to the predicted probability of failure. This rule based on the assumption that the components exhibit a constant failure rate, and if λ_i is the failure rate of component i , i= 1,.... , m , λ_s is termed the predicted system failure rate

Where $\lambda_s = \sum_{i=1}^{m} \lambda_i$ ...(2)

λ^*s be the specified system failure rate which is assumed to be less than λs. To compute the required failure rate for component i which is denoted by λ^*i , i = 1,2,…,m , we use the following equation :

$\lambda^*_i\, t = (\lambda_i t/\lambda_s t).\ \lambda^*_s\, t$ ...(3)

So the reliability goal for the component i is

$R^*_i(t) = e^{-(\lambda^* i)\, t}$ ...(4)

<u>**illustrative example**</u> :

A system consists of elements A, B, C and D connected as shown in fig (3) , the predicted reliabilities of the components are as follows R_A= 0.85, R_B=0.9, R_C = 0.8, R_D = 0.95 .

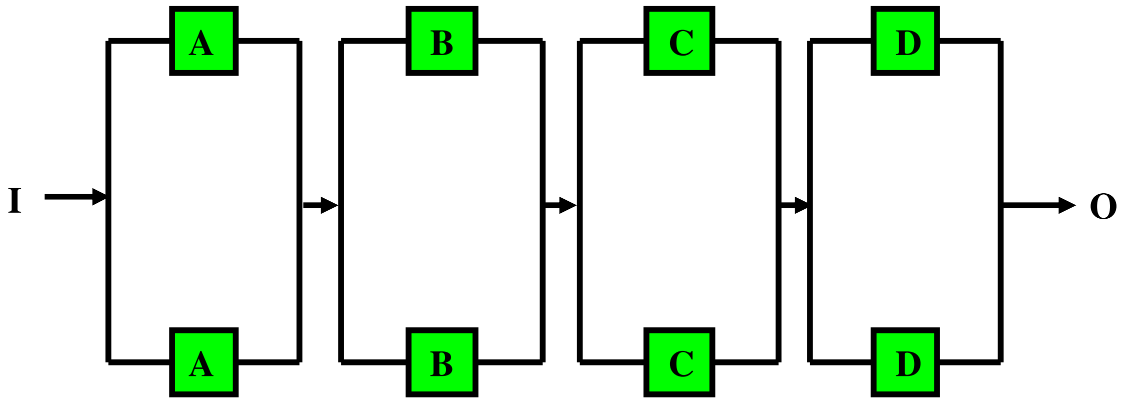

Fig (3) parallel – series system

if the system reliability is to be improved to a value of 0.97, determine the reliability goal of each component. Assume constant failure rate of all elements.

solution :-

1- To evaluate the reliability goal of each element , the given elements A,B,C and D are replaced by an equivalent single elements say P_1, P_2, P_3 and P_4 respectively.

   by making use eq. (1)

$$R_{P1} = 1-(1-R_A)^2 \Rightarrow R_{P1} = 1-(1-0.95)^2$$

$$= 0.99$$

$$R_{P2} = 1-(1-R_B)^2 \Rightarrow R_{P2} = 1-(1-0.99)^2$$

$$= 0.99$$

$$R_{P3} = 1-(1-R_C)^2 \Rightarrow R_{P3} = 1-(1-0.9)^2$$

$$= 0.99$$

$$R_{P4} = 1-(1-R_D)^2 \Rightarrow R_{P4} = 1-(1-0.96)^2$$

$$= 0.99$$

now the given system has been reduced to a series system as shown in fig (4)

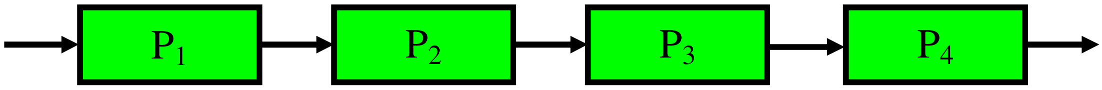

fig.(4)

We have, the reliability of the system is

The value of λt would have been $\lambda_{P1} t = \lambda_{P2} t = \lambda_{P3} t = \lambda_{P4} t = 0.01$

2- Thus the system reliability is given by

$$R_{System}(t) = R_{P1}(t) \times R_{P2}(t) \times R_{P3}(t) \times R_{P4}(t)$$

$$= \exp [-(\lambda_{P1}t + \lambda_{P2}t + \lambda_{P3}t + \lambda_{P4}t)]$$

$$= \exp - (\lambda_S t)$$

Where $\lambda_S t = 0.01+0.01+0.01+0.01= 0.04$

$R_{System}(t) = \exp(- 0.04) = 0.96$

3- The desired reliability $R^*_{System}(t) = 0.97$ for the system, there fore

$$R^*_{System}(t) = e^{-\lambda^*_s t} = 0.97 \Rightarrow \lambda^*_S t = 0.03$$

$$R^*_{System}(t) = \exp(-\lambda_{P1} t) \times \exp(-\lambda_{P2} t) \times \exp(-\lambda_{P3} t) \times \exp(-\lambda_{P4} t)$$

$$\lambda^*_{P1} = (\lambda^* s/\lambda s)\, \lambda_{P1} \,,\ \lambda^*_{P2} = (\lambda^* s/\lambda s)\, \lambda_{P2}$$

$$\lambda^*_{P3} = (\lambda^* s/\lambda s)\, \lambda_{P3} \,,\ \lambda^*_{P4} = (\lambda^* s/\lambda s)\, \lambda_{P4}$$

Hence, the allocated reliabilities are

$$R^*_{P1}(t) = \exp - (\lambda^* s/\lambda s)\, \lambda_{P1} \quad ;$$

$$R^*_{P2}(t) = \exp - (\lambda^* s/\lambda s)\, \lambda_{P2} \quad ;$$

$$R^*_{P3}(t) = \exp - (\lambda^* s/\lambda s)\, \lambda_{P3} \quad ;$$

$$R^*_{P4}(t) = \exp - (\lambda^* s/\lambda s)\, \lambda_{P4} \quad ;$$

$R^{*}_{P1}(t) = \exp - (0.03/0.04)\ 0.01 = 0.0075$

$R^{*}_{P2}(t) = \exp- (0.03/0.04)\ 0.01 = 0.0075$

$R^{*}_{P3}(t) = \exp- (0.03/0.04)\ 0.01 = 0.0075$

And $R^{*}_{P4}(t) = \exp - (0.03/0.04)\ 0.01 = 0.0075$

4. Conclusions

1- The reliability allocation is depending on the way with which the elements of the system are connected.

2- The process considered in this paper is the converse of that for calculating the system reliability.

3- This method used to calculate the reliability allocation for more general structure of parallel - series systems.

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