Improvement of Agree Allocation Method

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Abstract—Reliability allocation is an important step of system design. The design scheme for the system is directly under the influence of allocation results. AGREE is one major method for reliability allocation. In this paper, the deficiency of AGREE method was discussed, such as the depiction of importance and its applicability. Fault damage degree and fault influence degree were introduced. Through improvement of the traditional method, new allocation models for both serial and parallel connection systems were designed. Because of the improvement of this method, not only the allocation results will be more practicability, but also the application range will be wider. At last, an example was given, which demonstrate the validity and feasibility of the improved AGREE method.

Keywords—reliability allocation, AGREE, importance, complexity

I. INTRODUCTION

Reliability allocation is an important step of system design. It allows determination of the reliability of subsystems and components so as to obtain targeted overall system reliability. According to certain rules, the quantified reliability demand of the system can be allocated to each component through reliability allocation methods. The product designers can make the reliability demand clearly after the system’s reliability index was allotted to each level of the product.

Reliability allocation can offer reliability design index for product designer, which will ensure the system’s reliability accord with the requirement. What’s more, reliability allocation can make the reliability index clearly for the undertakers and providers of the system, which is convenient for them to supervise the product reliability. Hence, a reasonable reliability allocation scheme can lead the system to reach a stated reliability target economically and efficiency.

II. TRADITIONAL ALLOCATION METHOD OF AGREE

A. Allocation Principle

AGREE allocation method is a kind of reliability allocation method, which was brought forward by Advisory Group on Reliability of Electronic Equipment (AGREE) in America. The complexity, importance and work time of each subsystem was considered in this method. The basic standpoint of this method are as follows: the more complex subsystem is more vulnerable to fail, which should be assigned to a low reliability index; the more important subsystem is less wanted to fail, which should be allocated to a high reliability index.

B. Deficiency of AGREE Allocation Method

From the allocation modal above, we can see that the importance and complexity of the subsystem can directly influent the system’s reliability. Through all this influence factors were considered in AGREE allocation method, there are certain deficiency in the depiction of importance and its applicability.

1) Conceptions of importance and complexity

Importance means the important degree of the subsystem or component, which indicates the influence of subsystem fault on the system. The definition of importance can be shown as follows:

$$\omega_i = \frac{N_i(j)}{r_i(j)}$$

(1)

Where $N_i(j)$ means the number of failures which was caused by the subsystem $i$ (unit $j$); $r_i(j)$ means the number of failures of subsystem $i$ (unit $j$).

Complexity can be expressed by the proportion between basic constitute parts number of subsystem and system, which is shown as follows:

$$C_i = \frac{n_i}{N} = \frac{n_i}{\sum_{j=1}^{n} n_i}$$

(2)

Where $n_i$ means the basic constitute parts numbers of the subsystem $i$; $N$ means the basic constitute parts numbers of the system; $n$ means the numbers of the subsystems.

2) AGREE allocation model

The traditional AGREE allocation model can be shown as follows:

$$\lambda_i(j) = \frac{-n_i}{N \cdot \omega_{i(j)} t_{i(j)}} \ln R_s = - \frac{C_i}{\omega_{i(j)} t_{i(j)}} \ln R_s$$

(3)

Where $\lambda_i(j)$ denotes the allocated failure ratio of subsystem $i$ (unit $j$); $R_s$ is the system reliability goal.

B. Deficiency of AGREE Allocation Method

From the allocation modal above, we can see that the importance and complexity of the subsystem can directly influent the system’s reliability. Through all this influence factors were considered in AGREE allocation method, there are certain deficiency in the depiction of importance and its applicability.
1) The factors of importance is incomprehensive
According to the traditional AGREE method, only the number of system’s failure was considered, which was caused by subsystems. However, the influence of the subsystem’s failure was not considered in the depiction of importance. In the practice, only with the number of failures of subsystems, we can not say the subsystem whether is important or not. For example, subsystem A has failed ten times during T; among them they are three times lead the system failed, and all with serious influence to the system; subsystem B has failed ten times during T. Among them there are six times lead the system to fail, and all with gently influence to the system. From the information above, we can not judge which subsystem is more important. The more scientific method is that we should synthetically consider the importance with fault sequent. In other word, the influence factors for importance should include the number of failures of each subsystem and the influent degree of each fault.

2) The applicability needs to be developed
During the deducing course of this method, the supposing condition is that the system is an in series system with many subsystems. As a result, this method did not consider the parallel connection system or mix connection system. Hence, there are some deficiencies for this method.

III. IMPROVEMENT FOR AGREE METHOD

A. Parameters Introduction
1) Fault damage degree
Fault damage degree is a damage degree for the system which was caused by subsystems or components, and is denoted by $\beta_{i,j}$. The fault damage degree is between 0 and 1. Generally, when the subsystem’s failure lead to a tragedy sequent for the system, we consider fault damage degree is 1; while with serious sequent, universality sequent and gently sequent, the fault damage degree should equal to 0.8, 0.5 and 0.1.

2) Fault influence degree
Fault influence degree is a probability that the failure of subsystems or components will lead to the system fail. It is often marked by $\omega_{i,j}$, which denotes the probability that the fault of subsystem i (number of failure is j) will lead the system to fail.

B. Calculation of Importance
The fault damage degree of subsystem i can be expressed by row vector($\beta_{i,1}, \beta_{i,2}, ..., \beta_{i,n}$), while the fault influence degree can be expressed by columns vector($\omega_{i,1}, \omega_{i,2}, ..., \omega_{i,n}$). Then the improved importance of subsystem i can be denoted as follows:

$$\alpha_i = \frac{1}{n} [\beta_{i,1}, \beta_{i,2}, ..., \beta_{i,n}] [\omega_{i,1}, \omega_{i,2}, ..., \omega_{i,n}]^T$$  (4)

C. Reliability Allocation for Series Connection System
If the system configuration is series connection, and the system’s work time is T, while each subsystem’s work time is $t_i$, then the system’s failure ratio can be expressed as follows:

$$\lambda_i T = \sum_{i=1}^{n} \alpha_i \lambda_i t_i$$  (5)

So, we can get the proportion value of unit i to the system’s failure. $\lambda_i = \frac{n_i}{N}$

The complexity of each subsystem to the system can be denoted as $n_i / N$, where $n_i$ is the number of the component which included in subsystem i; N is the total component number of the system. We can suppose that the number of failure of the system and the number of components in the subsystem are shared pro rata, where the number of failure of the system is the fault number which was caused by subsystem’s failure.

$$\frac{\lambda_i t_i}{\lambda_i T} = \frac{n_i}{N}$$  (6)

Put $\lambda_i = \alpha_i \lambda_i$ into formula (6), so we can get:

$$\frac{\alpha_i \lambda_i t_i}{\lambda_i T} = \frac{n_i}{N}$$  (7)

For the series system, the system’s reliability can be denoted as $R^*_s(T) = e^{-\lambda_i T}$. Then, after synthetically considered importance and complexity, the assigned reliability parameter for subsystem i can be expressed as follows:

$$\lambda_{i}^* = \frac{n_i \lambda^*_s T}{N \alpha_i t_i}$$  (8)

Furthermore, the mean life of unit i can be expressed as:

$$\theta_{i}^* = \frac{N \alpha_i t_i}{n_i \ln R^*_s(T)}$$  (9)

Formula (8) and (9) are the allocation modal of improved AGREE method for series system.

D. Reliability Allocation for Parallel Connection System
For parallel connection system, the system will fail only after all subsystem failed. In other word, the system’s reliability is decided by the one which has the longest life-span in all subsystems.

When reliability index was allotted for parallel connection system, we can suppose each subsystem obey the same exponent distributing, without consider importance and
complexity, the assigned mean life for each subsystem can be denoted as follows:

\[
\theta^* = \frac{\theta_S}{\sum_{i=1}^{n} S_i}
\]

Taking the above as benchmark, when consider importance and complexity, we can get the assigned mean life for each subsystem by adding gene allocation method, which is shown as formula (11), where \( k_i \) is the importance weight for subsystem \( i \), \( S_i \) is the complexity weight for subsystem \( i \):

\[
\theta_i^* = \frac{k_i \sum_{i=1}^{n} S_i}{\sum_{i=1}^{n} k_i} \theta^*
\]

\[
k_i = \frac{\alpha_i}{\sum \alpha_i}, \quad S_i = \frac{n_i}{N}
\]

IV. CALCULATION EXAMPLES

There is a system composed of five subsystems, and the basic components of each subsystem are 102, 91, 95, 242, 40. The number of failure and failure influence is shown in table 1. If we design the system’s reliability is 0.923 with 12 hours working. Please allot the reliability index for each subsystem.

| TABLE I. NUMBER OF FAILURE AND FAILURE INFLUENCE OF EACH SUBSYSTEM |
|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| Subsystem | Fault Damage Degree | Fault Influence Degree | Work Time |
| A | 2  2  1  2  2 | 1  0  1  1  2 | \( \alpha_u = 1 \) |
| B | 1  0  1  0  1  | 1  1  1  1  2 | \( \alpha_v = 1 \) |
| C | 0  2  3  1  3  | 1  0  1  1  2 | \( \alpha_w = 0.8 \) |
| D | 2  1  2  2  2  | 1  1  2  2  2 | \( \alpha_x = 0.6 \) |
| E | 1  0  1  0  1  | 1  1  1  1  2 | \( \alpha_y = 0.8 \) |

Solution:

According to the improved AGREE allocation method, the importance of each subsystem are shown as follows:

\[
\alpha_u = \frac{1}{4} \left[ 0.5, 0.8, 0.1, 1.0 \right] [1, 1, 1, 1] = 0.825
\]

\[
\alpha_v = \frac{1}{4} \left[ 0.8, 1.0 \right] [1, 1] = 0.9
\]

\[
\alpha_w = \frac{1}{4} \left[ 0.8, 0.8, 0.1, 0.1 \right] [1, 0, 9, 0.9] = 0.84
\]

According to formula (9), we can get the allocation mean life \( \theta_i^* \) for subsystem A.

\[
\theta_A^* = \frac{570 \times 0.825 \times 12}{91 \times 0.923} = 690.5
\]

In the same way, we can calculate the mean life of subsystem B, C, D, and E, there are 844.2, 28.8, 282.4 and 1387.1 respectively.

According to \( R_i = e^{-\lambda_i t} \), we can get each subsystem’s reliability which is 0.9828, 0.9859, 0.9841, 0.9629 and 0.9938 respectively.

By checking computations for system reliability, we can get the system’s reliability is 0.9231, which satisfied the system’s reliability goal (0.923).

\[
\lambda_T = \sum_{i=1}^{n} \alpha_i \lambda_i t_i = 0.08
\]

\[
R_T(12) = e^{-\lambda_T \times 12} = 0.9231
\]

V. CONCLUSIONS

Having been partly ameliorated, the veracity and applicability of the AGREE allocation method are improved in a certain extent. This improvement is significant for solving reliability allocation problem efficiently. However, in the view of application, there are two issues should be develop in the future. One is how to develop this method to solve the reliability allocation for repertory systems, vote systems and other complex systems. The other one is how to synthetically consider more factors such as conditions, maintenance, quality and technique in reliability allocation.

REFERENCES


