Using Reliability Analysis for Optimum Scheme

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Abstract—This paper presents a method for project optimum scheme with the use of reliability qualitative analysis which analyzes the options of a project from the view of reliability. According to the results of reliability model, failure mode and effect analysis (FMEA) and failure tree analysis (FTA), the optimum scheme can be obtained with the contrast of reliability, the number of faults, the number of single point failures and the minimal cut set. Finally, this paper proves the feasibility of this method via an example of power supply and distribution system of XXX instrument.

Keywords- optimum scheme; reliability model; FMEA; FTA

I. INTRODUCTION

With the development of research on projects, more and more factors should be considered for the optimum scheme of a program. In general, most of the factors can be divided into two types. The first type of the factors is technical feasibility [1-3], such as easy to design, install. The other one is economic feasibility [4-5], e.g. procurement costs, construction costs. When the differences on the technical feasibility and the economic feasibility between the options of the program are tiny, or the economic restriction can be neglected (such as defense projects, equipment type etc.), it will be difficult to choose the optimum scheme just from the point of the technical feasibility and the economic feasibility. A method to acquire the optimum scheme from the view of reliability is proposed to solve the problem in the aforementioned situation.

II. APPLICATION OF RELIABILITY ANALYSIS FOR OPTIMUM SCHEME

For the convenience, we assume XXX system has two design options, which both meet the functional requirements of the system. The differences on cost between them are small, while there are large differences on system structure. This paper presents the contrast of these two options from the perspective of reliability as shown Fig. 1 [6-9].

Figure 1 method using reliability for optimum scheme
A. Contrast of Reliability

First we analyze the function of these two options and build the reliability model of the system with given mission profile, and then calculate the mission reliability of these two options using the data known or assumed. Then the reliability can be compared.

Even the design department doesn’t have the reliability data, the reliability of the system can also be calculated with the data assumed, which doesn’t affect the final result.

B. Contrast of the Number ofⅠ,Ⅱ-type Fault and Single Point Failure

When failure mode and effect analysis (FMEA) of these two options are accomplished, we can compare the number ofⅠ,Ⅱ-type fault and single point failure.

Similarly, when the design department doesn’t have the failure model data, on the one hand, the analysis person can use the failure model database from national standard, military standard and relevant professional standard, and also can communicate with design engineer in order to get fault information. The fault information which doesn’t need specific data is descriptive and can be got easier than the past quantitative analysis; on the other hand, we can use the similar product’s fault information of which credibility is higher than the quantitative data. First, the analysis person analyzes the cause of the failure according to the function and principle of the system. Second, the effect of the failure and conforming classification of the severe degree is analyzed. Finally, whether the failure is single point failure will be determined.

C. Contrast of the Minimal Cut Set

In this part, we need to carry on failure tree analysis (FTA) on each option of the system, and then the minimal cut set of both options can be gained and compared. If the number of the minimal cut set is large, we just need calculate first-order. On the contrary, we need to calculate second-order, third-order, fourth-order and so on.

Similarly to FMEA, if there is no failure information gathered by design department, the analysts can communicate with the designers or users so as to get the classic failure event which would be used as the top event on FTA. Then according to the function and principle of the system, the analysts analyze the failure events step by step. Finally, the basic event can be confirmed.

When the failure tree is finished, the analysts not only can calculate the minimal cut set, but also can calculate the probability of top event, probability importance, structure importance and critical importance of basic events according to the probability of basic event given or assumed. Then we can compare these data one by one.

D. Feedback and Tradeoff

In the process of calculation and contrast mentioned above, the analysts should make use of reliability model, the results from FMEA and FTA in order to find out the weakness of every option. Then we can bring out some advice for the improvement of the system, which will feedback to the designers. After some changes, the result should be calculated and compared again. In this way, a satisfactory solution would be acquired in the end.

The other methods used to compare the options of system can’t have this advantage. The method presented in this paper can continually optimize the system’s options in the process of analysis so as to obtain the optimum scheme.

III. EXAMPLE

A. Example Introduction

Now there are two design options for power supply and distribution system of XXX instrument. The first option is distributing the electricity separately, of which functional hierarchy is shown as Fig. 2. Second is distributing the electricity together, of which functional hierarchy is shown as Fig. 3. Both options are feasible to be realized in economical and technical aspects.

```
  XXX power supply and distribution system
    power supply and distribution system for Control and Use
      Battery 1
      Interface of Battery and Electric distributor 1
      Electric 1
      Electric Cable 1
    Interface of Electric Cable and System 1
    Battery 2
    Interface of Battery and Electric distributor 2
    Electric 2
    Electric Cable 2
  power supply and distribution system for Measure, Telemetering and Security Control
    Interface of Electric Cable and System 2
```

Figure 2: Functional hierarchy of the system with power supply and distribution separately

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B. Contrast of Options

Because of the limitation of passage length, this part doesn’t introduce the process of reliability analysis in detail. This part just lists part of the assumptions and the results of reliability analysis.

In the process of reliability modeling and analysis, we assume that all the batteries have the same failure rate, all the electric cables have the same failure rate and all the interfaces have the same failure rate. With this condition, reliability model on both cases can be acquired. Further, we assume the reliability of each unit is 0.999. Then a conclusion can be drawn:

**TABLE 1: CONTRAST OF SYSTEM RELIABILITY**

<table>
<thead>
<tr>
<th>Reliability</th>
<th>Power Supply separately</th>
<th>Power Supply together</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power supply and distribution system</td>
<td>0.9569</td>
<td>0.9888</td>
</tr>
</tbody>
</table>

From Table 1, we can see that the reliability of system with power supply and distribution together is higher. However, because of the capacity of the battery used in this two systems are different, we need to analyze further.

With FMECA on both systems, a table which compares the number of I , II -type fault and single point failure can be acquired as shown in Table 2.

**TABLE 2: CONTRAST OF RESULTS FROM FMEA**

<table>
<thead>
<tr>
<th>Number</th>
<th>Power Supply separately</th>
<th>Power Supply together</th>
</tr>
</thead>
<tbody>
<tr>
<td>I,II-type Fault</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Single Point Failure</td>
<td>21</td>
<td>2</td>
</tr>
</tbody>
</table>

From the table above, the number of I ,II -type fault and single point failure on the system distributing the electricity together is obviously smaller than the other system. This is mainly because that the systems with power supply and distribution together uses the measure of dual redundant power supply. Simultaneously, the weak links in the system with power supply and distribution together are the negative bus-bar and its interfaces of the five instrument power supply. As the failure rate of the cable is very small, this makes the weak links in this system less.

The failure tree of the power supply and distribution system for use and control is shown as Fig. 4(others omitted).

![Figure 4: Failure tree of power supply system for use and control](image)

When FTA on these two systems is finished, Table 3 which compares the number of failures that the number of the minimal cut set is first-order can be obtained.

It can be concluded that the system with power supply and distribution together has obvious advantage on successfully supply the instruments compared with the other system in different phases of electricity supply (ground power supply separately, ground power and battery supply simultaneously, ...
battery supply separately), which is mainly reflected on the decrease of the number of the first-order failures.

<table>
<thead>
<tr>
<th>Number of Single Point Failure</th>
<th>Power Supply separately</th>
<th>Power Supply together</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power supply and distribution system with Ground Power</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>Power supply and distribution system with Battery and Ground Power</td>
<td>23</td>
<td>9</td>
</tr>
<tr>
<td>Power supply and distribution system with Battery</td>
<td>11</td>
<td>3</td>
</tr>
</tbody>
</table>

Through the analysis above, the conclusion that the system with power supply and distribution together is superior to the system with power supply and distribution separately can be drawn. As a result, we select it as the optimum scheme.

C. Advice for Improvement

In the process of reliability analysis, it is found that the weakest link in the system of power supply and distribution together is the cables and its interfaces for power supply. Accordingly we need to improve its reliability level and pay attention to the installation technology. Both options apply self-holding circuit, if some problems happen on the self-holding relay, it will directly affect the power supply and distribution to the system. As a result, it needs pay a great attention.

In addition, in the phase of power supply and distribution with battery, it needs to improve the reliability level of the negative bus bar and its interfaces in the system of power supply and distribution together. In the phase of power supply and distribution with ground power, it needs to pay attention to the reliability level of switch for ground control, relays and relays for total power supply. It needs to improve the reliability level of the repeating switches and the repeating relays in the time of power supply and distribution with battery and ground power as a reason for that the failures happened on them will directly make power supply and distribution to the system fail.

IV. CONCLUSION

It has been forty years since reliability proposed in china, since then many achievements have been acquired on defense equipments. However, research on the reliability for optimum scheme was rare in China. This paper presents a method using reliability analysis for optimum scheme, and it is proved successful with application to a power supply and distribution system on XXX instrument.

REFERENCES