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THE APPLICATION FOR FAULT DIAGNOSIS AND PREDICTION OF POWER SYPPLY CONTROL DEVICE ON BEPCII

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Abstract

With the widely adoption of complex electronic devices and microcircuits in accelerator system, the probability of system failure and functional failure will be enlarged. For example, the fault of the magnet power supply front-end electronics devices may cause accelerator energy instability and even lead to beam loss. Therefore, it is very necessary to diagnose and locate the device fault accurately and rapidly, that will induce the high cost of the accelerator operation. Faults diagnosis and prediction can not only improve the safety and reliability of the equipment, but also effectively reduce the equipment's cycle costing. We applied the FMECA and testability modelling method for the PSI device, which using in BEPCII power supply control system, and evaluated the remaining life of the PSI under certain temperature and humidity condition based on the reliability model and accelerated life test.

INTRODUCTION

The complex electronic devices and microcircuits used in accelerator system is often the first part of the system to fail and lead to shorter service life of equipment or higher cost of system maintenance and operation steadily. In the Beijing Electron Positron Collider (BEPCII), hundreds of magnet power supplies are installed to provide power for various types of electromagnets, and the current of the power supply can be adjusted to change the magnetic field and thus control the orbit of particles. During the operation of the accelerator, failure of massive electronic devices may cause the accelerator energy to be unstable and even cause beam loss.

The traditional method to solve these problems is the fault diagnosis technology. However, fault diagnosis is generally only applied to the current fault status of the equipment. That is, the type and location of the fault are analyzed and diagnosed after the equipment fails, and cannot be pre-warned before the failure occurs. Besides, the cause of the failure of the electronic system is usually the combination of multiple failure modes and environmental stress. In actual, the issue of how to monitor the working status of electronic equipment in real time and provide early warning of possible faults is of great importance to improve the stable and reliable operation of the entire accelerator system.

TESTBILITY MODELLING

The testability modelling is a method to analyze the failure related information of equipment, which include two part at least. One is the Failure modes, effects, and criticality analysis(FMECA), that is a methodology to identify and analyze a product or process in order to determine all possible failure modes of various components in the system, how these failures affect the system, and what measures can be taken to avoid failures occurrence or reduction of the impact of a fault on the system [1]. In general, the method is to identify early in the product or process design all manner of failures so they can be eliminated or their impact reduced through redesign at the earliest possible time.

The other is testability modelling based on multi-signal flow graph [2], which combines the available test point configurations by analyzing the failure modes of each component in the system and the causes and effects of each failure mode. The Dependency Matrix $D=[d_{ij}]$ ($1 \le i \le m, 1 \le j \le n$, where m and n denotes the totality of the source of failure and the set of testing respectively) of whole device was established, and the Fault diagnosis is to find the candidate set of faults [3] based on the structure of multi-signal model. The testability modelling report is shown in Fig. 1. Because of the reliability of the constituent units is not same in practice system, it is necessary to ament the fault probability. There are two methods that can be used when correcting, Probabilistic Equalization Method and Probabilistic Priority Method. The Probabilistic Priority method is including the failure mode more comprehensively, and the obtained analysis result is better than the Probabilistic Equalization Method.

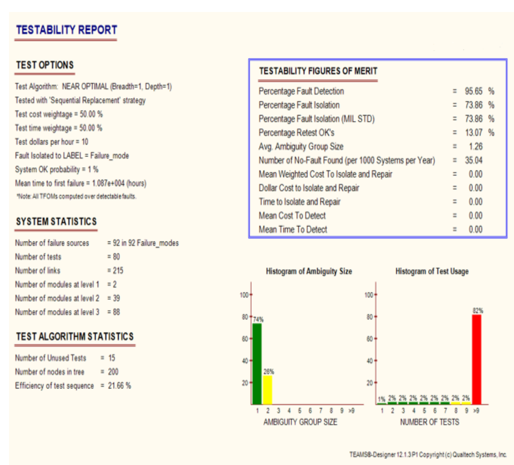

Figure 1: The testability report of power supply interface.

FAILURE PHYSICAL SIMULATION

Reliability Simulation, which based on Physics of Failure [4], is a reliability theory for establishing the relationship between failure and environmental stress from mechanism. Because of Temperature and vibration are the main factors that affect the reliability of electronic products, so

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vibration modeling and thermal modeling were performed for PSI. The result of simulation is shown in Fig. 2 and Fig. 3. The simulation analysis illustrate that the failure mechanism of PSI is the slight cracking of solder caused by the heating of connector components. The main function of this connector is to connect the voltage output from the power module to the interface board module, and 60% of the failure of PSI are related to this connector during the actual operation of BEPCII.

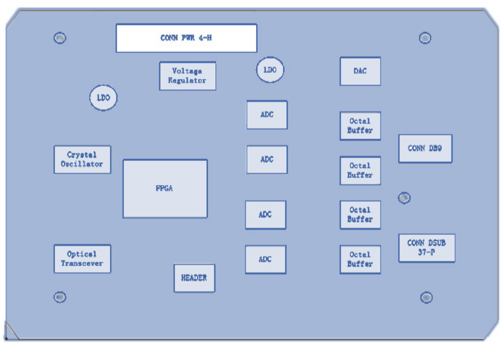

Figure 2: The vibration modelling of power supply interface.

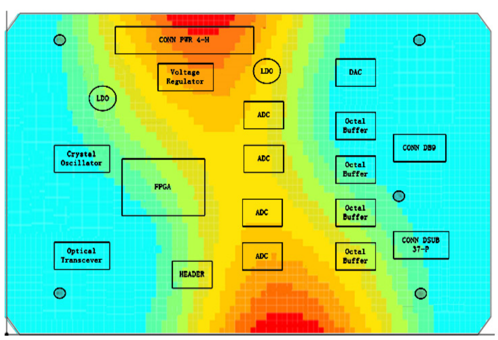

Figure 3: The thermal modelling of power supply interface.

REMAINING LIFE PREDICATE

The connector is located as the weak link of the whole PSI through the simulation, and then the Accelerated Degradation Test(ADT) is used to test the degradation process by increasing environmental stress without changing the mechanism of failure. ADT was carried out in a temperature and humidity alternating test box, several groups of temperature and humidity conditions were set up [5]. An oscilloscope is used to acquire and store the voltage that can characterize the connector. The degradation model was used to analyze the data obtained by the ADT. Based on the physical statistical model, the failure life can be associated with acceleration variables and the life or degradation rate of the equipment under normal operation can be estimated [6]. Usually, there are three degradation models for electronic equipment as Eq. (1)~(3),

$$y = \alpha_i + \beta_i t, \tag{1}$$

$$\log(y_i) = \alpha_i + \beta_i t, \tag{2}$$

$$log(y_i) = \alpha_i + \beta_i \log(t), \tag{3}$$

We chose the third model to fit the voltage experimental data of the PSI connector and obtain the degradation curve of equipment performance. The model under multiple-stress that considers the temperature and humidity conditions [7] is consistent with the logarithmic normal distribution:

$$\varepsilon = \beta_0 + \frac{\beta_1}{t+273.15} + \frac{\beta_2}{H} \tag{4}$$

The remaining life of PSI can be predicted by the reliability distribution curve, which is shown in Fig. 4.

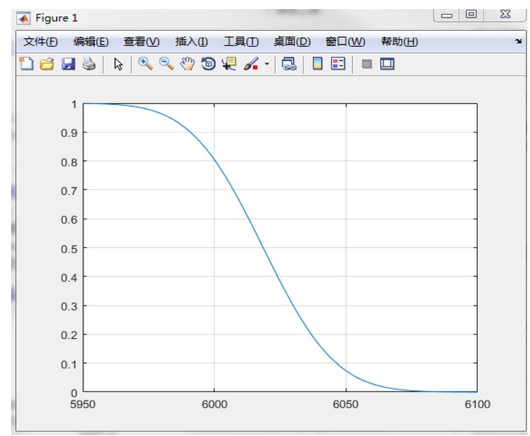

Figure 4: The algorithm normal distribution reliability of power supply interface.

SUMMARY

This paper introduces the basic workflow for fault diagnosis and prediction based on the PSI, the front-end electronic device used in BEPCII. It is used to obtain information about the faults of each component of the system through testability modelling analysis. And then perform the physical simulation of the system to determine the weak link of equipment. Based on the accelerated degradation test and reliability model, we can predict the remaining life of the device. However, the structure and function of PSI are relatively simple and the sample size of experimental data is too small, the large number of online data should be obtained to verify the validity of the prediction model.

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