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Reliability Analysis on NPP's Safety-Related Control Module with Field Data

Sang Yong Lee, Jae Hyun Jung, Seong Hun Kim
SAMCHANG ENTERPRISE CO., LTD. Control Technology Research Institute / R&D group
Reliability Research Team #974-1, Goyeon-ri, Woongchon-myon, Ulju-gun, Ulsan, KOERA, 689-871

1. Introduction

The automatic control systems used in nuclear power plant (NPP) consists of numerous control modules that can be considered to be a network of components various complex ways. The control modules require relatively high reliability than industrial electronic products. Reliability prediction provides the rational basis of system designs and also provides the safety significance of system operations. The aim of this paper is to minimize the deficiencies of the traditional reliability prediction method calculation using the available field return data. This way is possible to do more realistic reliability assessment. SAMCHANG Enterprise Company (SEC) has established database containing high quality data at the module and component level from module maintenance in NPP.

On the basis of these, this paper compares results that add failure record (field data) to Telcordia-SR-332 [1] reliability prediction model with MIL-HDBK-217F [2] prediction results.

2. Reliability Prediction and Comparison of Results

In this section the reason comparing the prediction results each prediction model is explained, the control modules used to predict MTBF are described, and prediction models (MIL-HDBK-217F and Telcordia-SR-332) is introduced. The approach is to compare estimates for reliability assessment of the control modules. In conclusion, we compare the prediction results that are based on data collected from field experience.

2.1. The discussion for comparison

The method used for reliability prediction is often a matter of contention. It is understood that the benefits of a reliability prediction are dependent on the accuracy and completeness of the information used to perform the prediction and on the methods used to conduct the prediction. [3] In case of MIL-HDBK-217F, many parts having the mil-spec is defined, but the model don't reflect the current or state-of-the-art parts in the electronic equipment; besides, while it is generally believed that reliability assessment methods should be used to aid in product design and development, the integrity and auditability of the reliability prediction methods have been found to be questionable; in that, the models do not predict field failures, cannot be used for comparative purposes, and present misleading trends and relations.[4] By reason of theses, we use the prediction result of Telcordia-SR-332 mixing the field data and compare it with the result of MIL-HDBK-217F.

The correct way to know the reliability of a product is the collection of field returns, the analysis of the data ad then failure analysis of the failed parts.[5]

2.2. Predicted Control Modules

Five control modules are selected to reliability prediction and these are NLP2, NSC4, NSA2, NLP3, NRA1 in 7300 process control system in KORI unit 2. These control modules have a signal conditioning function the same as converting many kind of signal and performing output limiting etc..

2.3. Application of Two prediction Models

2.3.1. MIL-HDBK-217F

This handbook has been the mainstay of reliability predictions for several years. it remains the most widely used prediction model by both commercial and military analysis. but it has not been updated since 1995. The handbook includes a series of empirical failure rate models developed using historical piece part failure data for a wide array of component types. There are models for virtually all electrical/electronic parts and a number of electromechanical parts as well. All models predict reliability in terms of failures per million operating hours and assume an exponential distribution (constant failure rate), which allows the addition of failure rates to determine higher assembly reliability. The handbook contains two prediction approaches: the parts stress technique and the parts count technique and covers 14 separate operational environments, such as ground fixed, airborne inhabited, etc. as the names imply, the parts stress technique requires knowledge of the stress levels on each part to determine its failure rate, while the parts count technique assumes average stress levels as a means of providing an early design estimate of the failure rate. We calculate the failure rate taking advantage of the parts stress method. The part failure rate in parts stress method is equal to follow.

$$\lambda_P = \lambda_b \pi_Q \pi_T \pi_E \pi_{oth} \quad (1)$$

λ_P = part failure rate (Failure/10e6 hours)

λ_b = base failure rate

π_Q = quality factor

π_T = temperature factor

π_E = environmental factor

π_{oth} = other factors

The general expression for module failure rate is represented as the following equation (2).

$$\lambda_M = \sum_{i=1}^{n} N_i(\lambda_p)i \quad (2)$$

λ_M = module failure rate

$(\lambda_P)_i$ = part failure rate for the i th specific part

N_i = quantity of the i th specific part

n = number of different specific part categories

In accordance with the equation (1), Detailed information for parts must be provided. Other factors include stress factors for each part.

2.3.2. Telcordia-SR-332

The Telcordia prediction model is widely used in the telecommunications industry and has been recently updated in May 2001. It is very similar to MIL-HDBK 217F. The model also assumes an exponential failure distribution and calculates reliability in terms of failures per billion part operating hours, or FITs. Its empirically based models are in three categories: Method Ⅰ parts count approach that applies when there is no field failure data available, the MethodⅡ modification to Method Ⅰto include lab test data and the Method Ⅲ variation that includes field failure tracking. In this work, we use the MethodⅢ, the data obtained from the PIMS(PCB Integrated Maintenance Service, including In Circuit Test) as field data is applied in calculation.
According to Telcordia-SR 332 MethodⅢ, The module failure rate combining the field data is calculated with equation (3)

$$\lambda_{SSi} = \frac{2+f}{\dfrac{2}{\lambda_{BBi}} + \dfrac{V \times t \times \pi_{Ei}}{10^9}} \quad (3)$$

λ_{BBi} = module failure rate using parts count method

f = failure number

V = correction factor

π_{Ei} = environment factor

t = total operating time,

t = N × T

N = inspected module number

T = operating time

2.4 Field data

SEC has an available failure data from PIMS as field data. We use this data and need the detailed information in the data that is equal to the failure number, operating time, inspected number for module. To calculate the module failure rate using parts count method, we also have the part list or part specification for module. The used data to predict the MTBF have been observed from 1996 to 2002 for 7 years.

2.5 Comparison of calculation results

To calculate the MTBF, Two prediction models is used for five control modules in 7300 process control system. Prediction results of MIL-HDBK-217F and Telcordia-SR-332 applying the field data for five control module is Table 1. Table1 shows that MIL-HDBK-217F prediction model is relatively conservative and the result of MIL-HDBK-217F on NRA1 has some excess. The excess don't made useful prediction results as effective means to perform the maintenance and replace the modules.

Module[MTBF,year]	NLP2	NSC4	NSA2	NLP3	NRA1
MIL-HDBK-217F	12.62	9.64	7.99	12.87	7.82
Telcordia-SR-332	13.63	13.01	10.28	17.81	20.29
Module[MTBF,hour]	NLP2	NSC4	NSA2	NLP3	NRA1
MIL-HDBK-217F	110589	84427	60059	112773	68466
Telcordia-SR-332	119418	113948	90059	156010	177727

Table1. Prediction results (MTBF)

3. Conclusion

Prediction results of MIL-HDBK-217F and Telcordia-SR-332 applying the field data for five control module are calculated and compared each other. The comparison analysis will increase the efficiency as life standard and the reference for preventive maintenance without the excess prediction value and therefore provide more reliable data in NPP.

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