The reliability analysis of the diversity structure of for integral reactor

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1. Introduction

It is commonly recognized that system reliability and functionality of digital system are better than those of analog system in general cases. Moreover, the digital system is superior in system operation and maintenance compared to the existing analog system. However, in spite of these advantages, there are also negative factors in the application of this new technology to the safety system design since there exists a potential in common mode failure of system operations. Generally, the diversity is adopted to prevent Common Mode Failure(CMF) of the Instrumentation and Control System (I&C) using digital technology in the nuclear fields. We implemented the diversity within a channel to prevent CMF of the Plant Protection System (PPS) using digital technology for integral reactor. Each PPS channel has two sets of different hardware. The purpose of this paper is to evaluate the effects on the reliability of PPS adopting the diverse mean and to assure the integrity of PPS. This paper shows that the result of reactor trip success probability of PPS is higher than the value of the analog system. Finally we demonstrate the integrity of PPS design in SMART Pilot Plant through the comparative analysis of results of the reactor trip success probability for PPS and that of existing analog one

2. Structure

Each channel of PPS for SMART Pilot Plant consists of Bistable Module, Coincidence Module, Reactor Trip Initiation Module, ESF Initiation Module, Maintenance & Test Panel (MTP), Safety-Grade Soft Controller (SGSC) and analog circuits for the final output. Each module consists of a Digital Signal Processor (DSP), Network Interface Card (NIC) and Reactor Trip Initiation Module including a Digital Output (DO) card. The bistable function determines the trip state by comparing the measured process variable to the predetermined setpoint value. The Coincidence module determines the state of the coincidence output based on the status of the four trip inputs and their respective trip channel bypass inputs. If a trip channel bypass is present, the coincidence logic is converted of 2 out of 3 logics, from the 2 out of 4 logics. Reactor Trip Initiation Module provides the reactor trip initiation signal for Reactor Trip Switchgear via the DO card. The MTP provides status information to operator and allows system testing, channel bypassing, setpoint entering and initiation circuits resetting. The SGSC is located in the main control room.

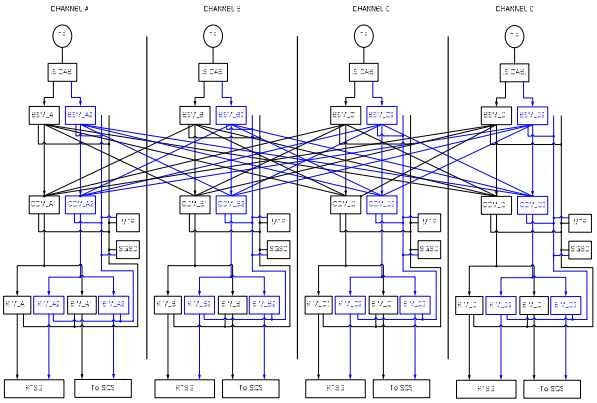

Figure 1 PPS Block Diagram

3. Reliability

3.1 Methodology

The reliability analysis related to the component parts of PPS is used the method that IEEE 352, MIL338B and MIL217F are offering. We calculated the reliability of each card using MIL217FN2 method based on the component of each card for the RPS. If we cannot evaluate a certain card, the minimum value is applied among the reliabilities applicable to the system. We selected the reliability value based on investigating the changeable parts on the structure block of card for the different hardware. We prepared functional block diagram and reliability block diagram based on the results of reliability analysis. The optimal signal flow and decision logic are adopted through the reliability block diagram. By comparing the reactor trip success probability calculated by suggested method above with the value calculated by the RBD method of the contents presented in the analog system we has performed the verification for the design. The comprehensive reliability analysis process in system is constantly continued.

This study performed following steps;

- Using the part stress analysis method of MIL-HDBK-217F, the reliability prediction data for each module is calculated.

- By the adopted assumption, the specific CCF parameter of each module is calculated.
- Through analysis of the process block diagram and circuit schematics, reliability block diagram is developed.
- For calculating the provability of the reactor trip fail, the reliability prediction values are applied to reliability block diagram as shown in Figure 2.

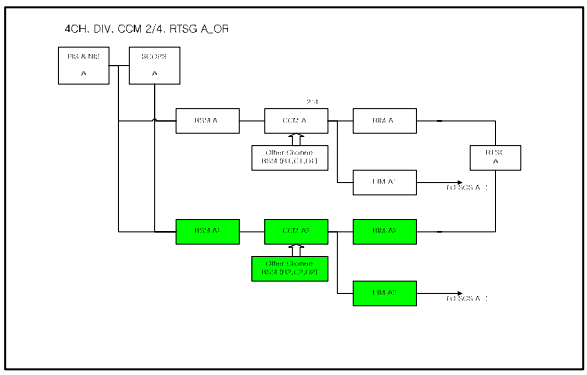

Figure 2 Reliability Block Diagram

3.2 Assumption

It is recognized that the MIL-MDBK-217 provides realistic base line data of component failure rates.
Reliability calculations of this study were selected from the data sources in MIL-HDBK-217F with the following assumptions;

1) Environmental factors of the study are selected from Ground Benign(GB) level.
2) Operating temperature of microcircuits, semiconductors, and other devices is selected as 40 ℃
3) CCF effect has only one state of the component.
4) Applied Multiple Greek Letter (MGL) factors based on generic parameter in NUREG/CR-5485.
5) Reliability analysis is focused on hardware and so Software reliability is not subject to calculates.

4. Result

To compare the reliability calculation result with different type of PPS, general component failure rate (shunt coil, under voltage coil, RTSG etc) is applied based on UCN 5&6. Using the values calculated for 3 type design concept system is following table.

Table 1 Reliability Calculation Result

TYPE	CH TRIP Signal	CH TRIP Action	RTSG Action
4CH Redundancy	1.51E-05	8.28E-05	1.36E-06
8CH Redundancy	4.79E-06	7.25E-05	1.04E-06
4CH DIV Redundancy	2.26E-08	6.78E-05	9.12E-07

By qualitative analysis of the four redundant systems with diversity in a channel, it has shown that the design concept is excellent. The system reliability calculations also show that failure rate is 9.12E-06/hour by approximate evaluation method. And result shows that the design concept of PPS for integral reactor is a highly reliable.

5. Conclusions

In order to determine the redundancy and diversity of digital system, the reliability of system should not be degraded. The result of the reliability analysis shows that the digitalized PPS was higher than the value of the existing analog system. The supplement of CMF quantity analysis related to the digital system is the subject for a future study.

REFERENCES

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