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The Analysis of Reliability for Two Types of Digital I&C Systems Using PSA Technique

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1. Introduction

For nuclear power plants, I&C systems require the utmost safety and reliability. For this, the license applicant of the power plant needs to assess the control system. Although various methods can be used for this assessment, this paper evaluates I&C systems as shown in section 2 using PSA. The CDF is the results from each I&C models using each logic and data sources.

2. Methodology

In order to evaluate the effect of I&C system on core damage using PSA, there are some assumptions and two different I&C system. The details are described as below.

2.1 Assumption

To evaluate the effect of two different I&C system, the PSA models need to have consistency and unity. And, the influence of I&C system need to be identified to be dominant. Therefore, the following assumptions are considered:

a. Modeled systems are only Plant Protection System (PPS) and Engineered Safety Features-Component Control System (ESF-CCS) for each case.
b. Except for the PPS and ESF-CCS, the PSA models (Fault Tree, Event Tree and Database) are fixed to be evaluated.
c. For increase the influence of control logic failures, manually control signals are excluded.
d. Failure of software for I&C system is not considered. Since, failure rate of software is not defined clearly for PSA.
e. The component would be controlled by control signal links (i.e. High Reliability-Safety Data Link, HR-SDL). The networks are only transferred status of I&C component. Therefore, signal links are modeled for this analysis.

Based on the above assumptions, the systems are modeled and applied in the following logics.

2-2 Logic for each I&C system

The CDF is calculated by using two PSA models which have different type of I&C system. One is Common-Q platform and the other is POSAFE-Q platform. So, in this section, these two types of I&C systems will be described as follows:

a. Common-Q Platform

The PPS includes Bistable Processor (BP) and Local Coincidence Logic (LCL). In each channel, the PPS consist of two BP and two sets of LCL, each set of LCL has four Processor Modules. The BPs compute and generate output signal about reactor trip and/or Engineered Safety Features Actuating Signal (ESFAS) based on various sensor signal and set point. And, each LCL receives BP signal from four channels. The LCL logic is selective two out of four ((A or C) and (B or D)). Also, two of the processors generate reactor trip signal, one of the processors generates ESFAS and the last one processor is spare.

The ESF-CCS includes Group Controller (GC) and Loop Controller (LC). Each channel of ESF-CCS has two sets of GCs and several LCs. The GC receives LCL signal that are generated in each channel. The GC logic is same as the LCL logic that is selective two out of four. Finally the LC does not have logic.

The detailed Common-Q logic is derived in Figure 1.

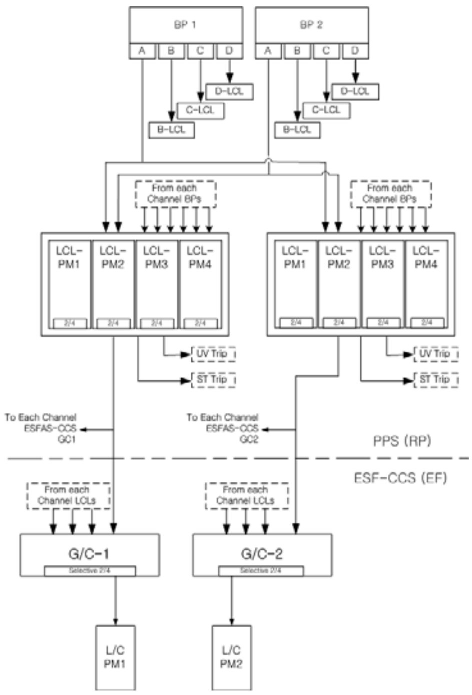

Figure 1. Common-Q platform signal flow

b. POSAFE-Q Platform

The PPS includes Bistable Processor (BP) and Coincidence Processor (CP). In each channel, the PPS consist of two BPs and three CPs. The BPs compute and generate output signal about reactor trip and/or ESFAS based on various sensor signal and set point. And, the each CP receives BP signal from four channels. The CP logic is full two out of four. Each CP generates reactor trip signal and ESFAS.

The ESF-CCS includes Group Controller (GC) and Loop Controller (LC). Each channel of ESF-CCS has three GCs and several LCs. The GC receives CP signal that are generated in each channel. The GC logic is full two out of four. Finally the LC has logic that is two out of three.

The detailed POSAFE-Q logic is derived in Figure 2.

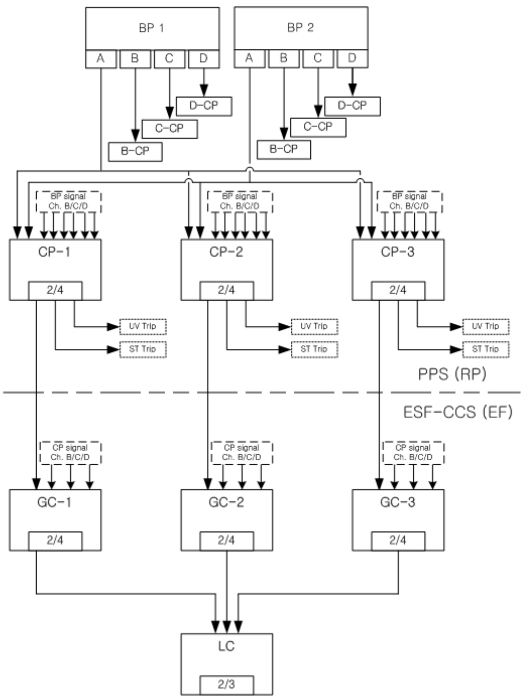

Figure 2. POSAFE-Q platform signal flow

2-3. Database for PSA

The failure data is not the same for two types of I&C system. So, these two data sources are used for analysis and each data source is as follows:

a. Common-Q type Platform
b. POSAFE-Q type Platform

Also, I&C system of two PSA model does not have same logic. Therefore, by comparing each data and applying these data to different PSA model as shown in Table 1, the difference of CDF between each case will be derived.

Table 1. Case for analysis

No. of Case	I&C Model	Data
Case 1	POSAFE-Q	POSAFE-Q
Case 2	Common-Q	POSAFE-Q
Case 3	Common-Q	Common-Q

3. Results

As a result of analysis, CDF of each case is derived as shown in Table 2. The highest CDF is Case 2, next is Case 3 and Case 1.

Table 2. CDF for each case

	I&C Model	Data	CDF
Case 1	POSAFE-Q	POSAFE-Q	4.16E-07
Case 2	Common-Q	POSAFE-Q	4.45E-07
Case 3	Common-Q	Common-Q	4.38E-07

Using these results, the CDFs are compared to get insights from the variation of data and PSA model.

The CDF variation results by comparison between Case 1, Case 2 and Case 3 are shown in Table 3. And, the results are described below.

- Comparison 1(case 1 vs case 3)

The results for each PSA model that respectively adapts digital I&C logic and data source of POSAFE-Q and Common-Q are compared. The result shows that digital I&C logic of Common-Q has higher value on CDF than digital I&C logic of POSAFE-Q. The CDF result from case 3 is 2.15E-08(5.2%) higher than case 1.

In the MCS (Minimal Cutsets) results, the dominant differences are CCF of GCs and communication modules (i.e. Fiber Optic Modem and Optic/Electric Data Link). Increased GCs and communication modules make the CDF higher. However, added logic for CP, GC and LC, make the CDF very lower. That is, the result is that the CDF reduction due to the increase of the logic is bigger than the increase of the control component.

- Comparison 2(case 2 vs case 3)

The results for each PSA model that respectively adapts data source of POSAFE-Q and Common-Q are compared. The different data sources are applied to the same PSA model that adapts digital I&C logic of Common-Q. The result shows that data for POSAFE-Q has relatively higher value than that of Common-Q. The CDF result from case 3 is 7.04E-09(1.6%) higher than case 2.

Overall, the MCS values contributing to CDF have increased, As mentioned above, this result means that the reliability data is more conservative than Common-Q.

- Comparison 3(case 1 vs case 2)

In this comparison, the results for each PSA model that adapts the same data source of POSAFE-Q are compared. The same data source is applied to the different PSA models that respectively adapts digital I&C logic of POSAFE-Q and Common-Q. The results shows that digital I&C logic of Common-Q has higher effect on CDF than that of POSAFE-Q. The CDF result from case 2 is 2.86E-08(6.9%) higher than case 1. As a result, digital I&C logic of POSAFE-Q has lower effect on CDF than that of digital I&C logic of Common-Q.

Several MCS are disappeared at truncation limit 1.00E-13. The major reason is the changed logic that changed from selective 2 out of 4 to full 2 out of 4, and added logic of 2 out of 3 to Loop Controllers.

Overall results of comparison are shown in Table 3.

Table 3. Comparisons between each case

Comparison	CDF variation	Rate of CDF increase (%)
Case 1 vs. Case 3	2.15E-08	5.2%
Case 2 vs. Case 3	7.04E-09	1.6%
Case 1 vs. Case 2	2.86E-08	6.9%

4. Conclusions

This analysis presents that the POSAFE-Q system is more reliable and safer than Common-Q system. However, this analysis considers only two systems (PPS and ESF-CCS) for evaluate CDF. In order to calculate more accurate result, PSA model should consider all I&C systems (i.e. P-CCS, DPS, DMA and etc.). In the future, by considering all I&C systems to PSA model, more improved results will be obtained.

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