Development of Monitoring Performance Criteria for the Reactor Protection & Engineered Safety Features Actuation Systems

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1. Introduction

Korea Hydro & Nuclear Power Co. (KHNP) is developing and implementing the Maintenance Rule (MR) programs based on NUMARC 93-01 rev. 3 for all of its nuclear power plants. As a part of this project, 10 Instrumentation & Control (I&C) systems were screened to be the scope of the Maintenance Rule implementation program for Westinghouse 900MWe plants in Korea.

In this paper, the entire process of developing the MR implementation program, i.e., scoping, risk significance and setting performance criteria will be introduced for two key I&C systems which are Reactor Protection System (RPS) & Engineered Safety Features Actuation System (ESFAS).

2. Function Identification & Scoping

The first step of MR implementing program development is to identify the functions of a system. Three functions based on the FSAR were identified for RPS. They are functions for providing reactor trip signal, permission & control signal and ESFAS actuation signal. For ESFAS, two functions, i.e., NSSS ESFAS and BOP ESFAS actuations were identified.

The scoping criteria to determine which functions should be scoped in for monitoring consist of three safety related functions (SR-1, SR-2 and SR-3) and four non-safety related functions (NSR1 through 4) [1]. The three safety related scoping categories are SR-1 which is the function related to the integrity of the reactor coolant pressure boundary, SR-2 which is the function related to the capability to shutdown the reactor and maintain it in a safe shutdown, and SR-3 which is the function related to the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to 10CFR Part 100 guidelines. The functions for RPS were scoped in as SR2 safety related functions while of ESFAS are as SR2 and SR3 functions.

The functions and scoping result for these systems are shown in table 1

FID	Function	Safety-related	SR1	SR2	SR3	NSR1	NSR2	NSR3	NSR4	MR scoping	standby
SA-01	NSSS ESFAS actuation	Y	N	Y	Y	N	N	N	N	Y	Y
SA-02	BOP ESFAS actuation	Y	N	Y	Y	N	N	N	N	N	Y
SB-01	Reactor trip signal actuation	Y	N	Y	N	N	N	N	N	Y	Y
SB-02	Providing ESF Actuation signal	Y	N	Y	N	N	N	N	N	Y	Y
SB-03	Providing Permission & Control signal	Y	N	Y	N	N	N	N	N	Y	Y

Table 1: Function classification & definition

Key components for each function were identified based on the scoping boundary and PSA model for those systems. The scoping boundary of each function is shown in Figure 1.

For the function analysis, SA-01(NSSS ESFAS actuation) was identified separately even though the slave relays of ESFAS are located in Solid State Protection System (SSPS) output cabinet [2].

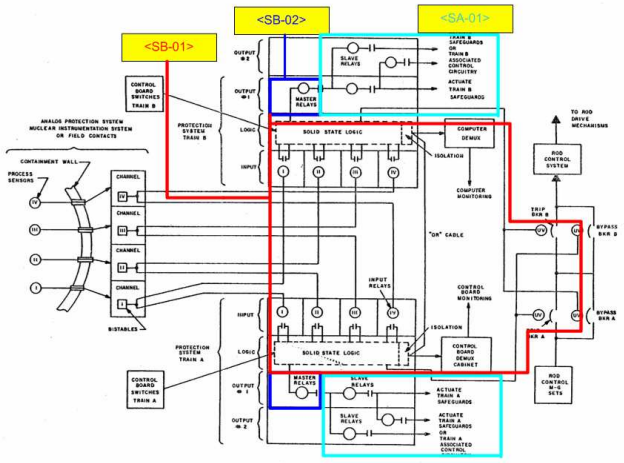

Figure 1: Schematic of Function boundaries [3]
(SB :RPS, SA :ESFAS)

3. Safety significance determination

The safety significance of functions is determined by using PSA results and Delphi method.

The Delphi method is utilized by the panel consisting of operation and maintenance experts. There are two categories of safety significance: High and Low. The results of safety significance determination are summarized in Table 2.

FID	Function	result
SA-01	NSSS ESFAS actuation	H
SA-02	BOP ESFAS actuation	H
SB-01	Reactor trip signal actuation	H
SB-02	Providing ESF Actuation signal	H
SB-03	Providing Permission & Control signal	L

Table 2: The list of Significance determination results

All functions for ESFAS and RPS are determined to be high safety significance (HSS) except SB-03 (Providing Permission & Control signal).

Main backgrounds of safety significance determination are as follows:

- SA-01: determined HSS by Delphi and PSA considering for each function Common Cause Failure (CCF) of slave relays.
- SA-02: determined HSS by Delphi because this is not modeled in the PSA (The expert panel determine the safety significance because it is 'required to shutdown the reactor and maintain it in a safe shutdown condition')
- SB-01: determined HSS by Delphi even though the PSA result was LSS due to redundancy. The reason is that 'reactor safety shutdown' is a very important function to mitigate an accident, even if there are other methods to shutdown the reactor [3].
- SB-02: determined HSS by Delphi and PSA considering the PSA Basic Event (BE) of Safeguard Output card Circuit Breaker Fails
- SB-03: determined LSS by Delphi and PSA considering General Transients assumed in the PSA model.

4. Development of Performance Criteria (PC)

Through the function dependency analysis and monitoring practice review, one PC (SA01) for ESFAS and two PC (SB01, SB02) for RPS were established.

The reliability and availability PC were established for ESFAS because it is a HSS function. In addition, For SA01, a population type PC was established as component level performance criteria to monitor the failure trend of slave relays of ESFAS. One failure is allowed per 3 years in accordance with PSA. APC for SA01 is 5.1 days per 3 years based on the 4 hours of AOT and surveillance test interval (test required every 120 hours).

The RPC for Reactor Protection System is "0", that is, no failure is allowed. Therefore Condition Monitoring Criteria (CMC) was established. Electronic circuit cards, master relays and reactor trip breakers for PC SB01 are monitored by CMC and power supplies for PC SB02 are monitored by CMC as well. For these components, number of failures allowed under the CMC is shown in Table 3.

Component	Allowable number	Basis
electronic circuit card	1	Based on PSA failure rate 7.11E-8 (Universal Logic Card), 1.38E-7 (Safe Output Card) and the number of cards is 53
master relay	1	Based on PSA failure rate 1.2E-7 (master relay fail to operate) and the number of relays is 31/train
reactor trip breaker	1	Failure-to-close allowed by using 95% reliability and the number of breaker is 4 (only failure- to-open is a function failure)
power supply	1	Although, the RPC value is 0.6 by using 95 % reliability, it was set to be one, since a single power supply failure does not cause a functional failure due to backup power supply

Table 3: Allowable number of failures for the RPS components

5. Conclusions

Because of the system complications of RPS and ESFAS, a lot of careful attention was needed to define functions and to set up performance criteria.

Especially, one of the most challenging difficulties was to determine whether the performance criteria should be established at the component level or loop level when setting performance criteria for these systems.

In this study, the condition monitoring performance criteria at the component level were determined because performance criteria for the loop level monitoring were found to be very complicated and various types of PC would be necessary for each loop construction system.

These performance criteria will be used for the initial evaluation of the RPS/ESFAS performance through the analysis of failure notices, which in turn will verify the appropriateness of these performance criteria.

REFERENCES

[1] Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants, July 2000, NUMARC 93-01 revision 3
[2] T. Y. Song, The Scoping of MR Standard Functions in WH900 NPPs, July 2008, KHNP NETEC
[3] Y. J. Kim, The Classification of MR Standard Risk significance in KHNP NPPs, July 2008, KHNP NETEC