Multiple Spurious Operation Scenario Analysis for CANDU Reactors

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1. Introduction

On March 22, 1975, the Browns Ferry Nuclear Power Plant had the worst fire ever to occur in a commercial nuclear power plant operating in the United States. The Special Review Group that investigated the Browns Ferry fire made recommendations pertaining to assuring that the effectiveness of the fire protection programs at operating nuclear power plants conform to General Design Criterion (GDC) 3[1]. NRC and NEI issued Regulatory Guide 1.189 and NEI 00-01 guidance that multiple spurious operations (MSO) should be addressed to an FHA process.

The regulatory body of nuclear safety in Korea requires Fire Hazard Analysis (FHA) to include the analysis of multiple spurious operations (MSO). Korea Hydro & Nuclear Power (KHNP) conducted CANDU MSO scenario analysis based on current NEI 00-01(Rev.3) to identify possible vulnerability due to MSO during fire events [2][3].

This paper illustrates the regulatory requirement for MSO, FHA & MSO analysis methodology and MSO scenario analysis results for CANDU reactors.

2. MSO Analysis Methodology and Results

2.1 Regulatory Requirement

In late 2015, Korean nuclear regulatory body (Nuclear Safety and Security Commission) has completed the full revision of technical standards for Fire Hazard Analysis including new MSO rules, reinforced regulation on Fire Protection Plan (FPP) and periodic (10 years) updating of FHA [4].

Table 1. Notice of NSSC for Fire Hazard Analysis

Main Contents	
Notice of the NSSC 2015-11	○ Full revision of technical standards for FHA(Fire Hazard Analysis) - FHA & PFSSA(Post-Fire Safe Shutdown Analysis) - Design criteria for Fire Protection - Methodology of Fire Hazard Analysis - Including MSO(Multiple Spurious Operation) analysis (for 24 operating NPPs)
Notice of the NSSC 2015-12	○ Regulation on Establishment and Implementation of FPP - Organizational structure, Role and Responsibilities, Education and Training - Fire prevention and response - Implementation status of FPP(Fire Protection Program) ○ Periodic(10years) updating of FHA & Implementation of FPP

2.2 Methodology for Fire Hazard Analysis

The objectives of the fire protection are achieving and maintaining capabilities for safe shutdown, decay heat removal and prevention of unacceptable release of radioactive materials under fire conditions. So we conduct FHA, which is a qualitative and quantitative fire hazard analysis to evaluate the capability of a nuclear power plant to perform safe-shutdown functions and minimize radioactive releases to the environment in the event of a fire. Figure 1 shows the process of FHA.

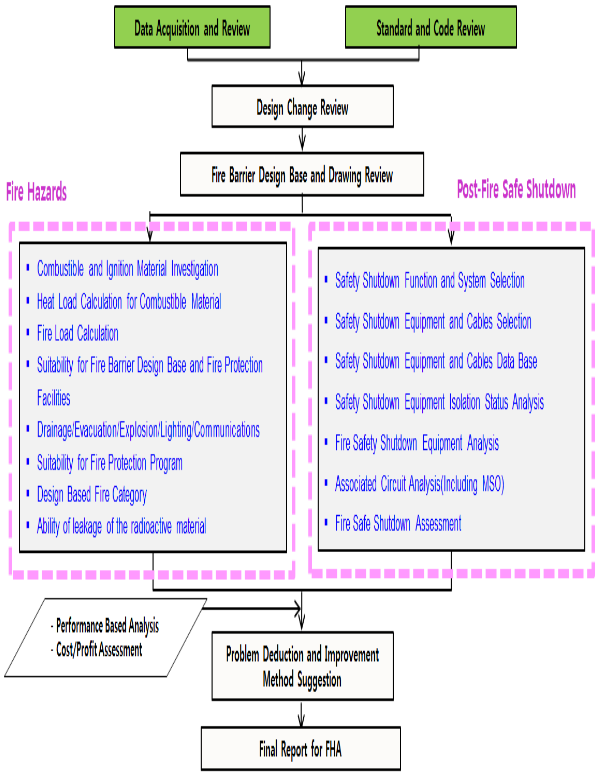

Fig.1. Fire Hazard Analysis Process

2.3 Methodology for MSO Analysis

Figure 2 is the MSO Analysis process created by KHNP with reference to NEI 00-01. This methodology is applicable to both CANDU and PWR reactors.

In the first step, we analyze the plant-specific MSO scenarios derived from a generic list of MSOs. This step includes developing an MSO list and a reviewing of all MSO scenarios by Expert Panel. The Expert Panel review is performed to systematically and completely review all spurious MSO scenarios and determine whether or not each individual scenario is to be included or excluded from the plant specific list of multiple spurious operation scenarios to be considered in the plant specific post-fire SSA.

In the next step, we develop component combinations using PSA technique and the safe shutdown equipment list(SSEL). The equipment that was not previously included in conventional FHA should be incorporated into the SSEL.

Then, we perform detailed circuit analysis. All components' initial positions and desired positions are determined based on the function state, so that relevant cables are identified. Potential fault modes are analyzed for open circuit, short to ground, hot short, and ground fault equivalent hot short(GFEHS).

Finally, we perform fire area compliance assessment. Impacts by specific MSOs are assessed on a fire area basis in the same manner as post-fire safe shutdown analysis. If some components and/or associated cables for a particular MSO scenario are allocated in a same fire area, there is potential for challenging plant safe shutdown. In this case, a mitigation strategy must be provided. There are two types of strategies depending on the roles of the component.

a) for Required Hot Shutdown components
   Cable Reroute, Re-analyze or Re-design Circuit
b) for Important to SSD components
   Means stated above, Operator Manual Action, Fire Modeling, Focused Scope Fire PSA

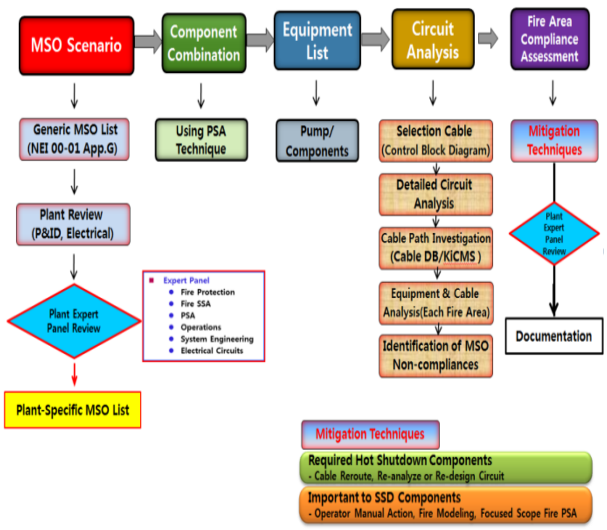

Fig.2. MSO Analysis Process

2.4 MSO scenario analysis results for CANDU

The MSO scenarios for CANDU reactors were analyzed using the above methodology, and the results are as follows;

CANDU MSO scenarios for RCP seal cooling are conceptually similar to those of PWRs, but system designs are different in detail. CANDU reactors don't have isolation valves for RCP seal supply, so we don't need to worry about spurious RCP seal header isolation. However, there are some conditions that might impact the seal integrity; if we don't have CCW system working for Coolant Purification System cooling, we will have heated seal water to inject. Under the situation if we can't close the valve on the line to RCP seal from Coolant Purification System, we are going to supply heated seal water to RCP seal. These two combination of spurious operation works like RCP seal header isolation in PWRs, and if we lose CCW for RCP bearings under the circumstance, we have CANDU MSO scenario 1b in Table 2. Scenario 1c is for loss of Degasser Cooler cooling with similar combination [5].

Table 2. MSO scenario analysis results for CANDU

ID#	SCENARIO	CLASSIFICATION
1a	Loss of PHT pump seal cooling	IMPORTANT
1b	Loss of PHT pump seal cooling	IMPORTANT
1c	Loss of PHT pump seal cooling	IMPORTANT
18	Multiple Pressurizer PORVs, ***Liquid Relief V/V, Degasser Condenser Relief V/V, PHT Vent Condenser V/V*** and Temp. control V/V OPEN	IMPORTANT
30	AFW Flow Diversion	IMPORTANT
31	AFW Pump Runout	IMPORTANT
36	PHT Pressure Decrease	IMPORTANT
37	PHT Pressure Increase	IMPORTANT
51	Generic - Pump Shutoff Head	REQUIRED
56e	PORV(s) Open; - (PORV(s) OR ***Liquid Relief v/v***) AND ***Degasser Condenser Relief v/v***	IMPORTANT

3. Conclusions

As the regulatory body of nuclear safety in Korea requires Fire Hazard Analysis (FHA) to include the analysis of multiple spurious operations (MSO), CANDU plants shall implement the MSO analysis for the post-fire safe shutdown. We could find that some PWR MSO scenarios from NEI 00-01 are applicable to CANDU reactors. Also, we could identify 3 CANDU specific scenarios for RCP seal integrity. KHNP has completed CANDU MSO scenario analysis and the results with some more following analysis are scheduled to be submitted to the regulatory body in June 2019.

REFERENCES

[1] U.S. Nuclear Regulatory Commission (NRC) Inspection and Enforcement (IE) Bulletin Nos. 50-259/75 and 50-260/75-1, 1975

[2] NEI 00-01, Guidance for Post Fire Safe Shutdown Circuit Analysis, 2011.

[3] R.G 1.189, Fire Protection for Nuclear Power Plants, 2009.

[4] Notice of Nuclear Safety and Security Commission, No.2015-11 and 2015-12, 2015.

[5] Multiple Spurious Operation Development for Wolsong Unit 2, 2018.