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Study on the Post-Fire Safe-Shutdown Analysis for CANDU NPPs

In Hwan Kim [a*], Yun Jung Kim [a *], Mun Hee Park [a]
[a] *Central Research Institute, 70, 1312-gil, Yuseong-daero, Yuseong-gu, Daejeon*
[*] *Corresponding author: kiminh77@khnp.co.kr*

1. Introduction

The purpose of Fire Protection is prevention, suppression of the fire and mitigation of the effect on the Nuclear Safety. When fire takes place at the Nuclear Power Plnats(NPPs), the reactor should achieve and maintain safe shut-down condition and minimize radioactive material release to an environment.

The purpose of this paper is to study a method of the Post-Fire Safe-Shutdown Analysis in order to apply to CANDU NPPs when one group of the Safety Structures, Systems and Components(SCCs) is failed by Fire.

2. Methods and Results

In this section, Post-Fire Safe-Shutdown Analysis (SSA) Process was reviewed and used to analyze control room complex of CANDU NPPs.

The Safe Shutdown Analysis should identify the fire impacts and ensure the measures to prevent damage from affecting safe shutdown. The selected systems for individual components and cables will be needed to ensure that each system should be accomplished its intended shutdown function.

2.1 The method of the Analysis

The detailed SSA methods used by a particular plant will vary in plant-specific conditions, such as designs, constructions, configurations, layouts, and operating preferences. So it is needed to ensure the availability of at least one shutdown “success path” because the processes for performing a deterministic analysis to satisfy Appendix R vary. Figure 1 illustrates the overview of the approach for the Post-Fire Safe-Shutdown Analysis Process[1].

2.2 The Results of Analysis

1) Establish Plant-Specific Basis for Analysis

This step is a documents review process to obtain information on the plant systems and functions required to achieve and maintain safe-shutdown.

The following documents should be collected for SSA. : Licensing Documents(FSAR, Technical Spec), System Descriptions, Design Drawings(piping and instrumentation diagrams, General Arrangement, Electrical drawings), Fire Hazards Analysis Report, and Operating Procedures(normal, abnormal, emergency).

2) Define Safe Shutdown Functions

Required shutdown functions must be accomplished and controlled to ensure that the reactor should achive and maintain the safe-shutdown conditions without exceeding the shutdown performance goals.

The shutdown functions for CANDU are Reactor Shutdown, Decay Heat Removal, Monitoring of Plant Parameters, Barrier to Fission of Product Release, and Support Services[2].

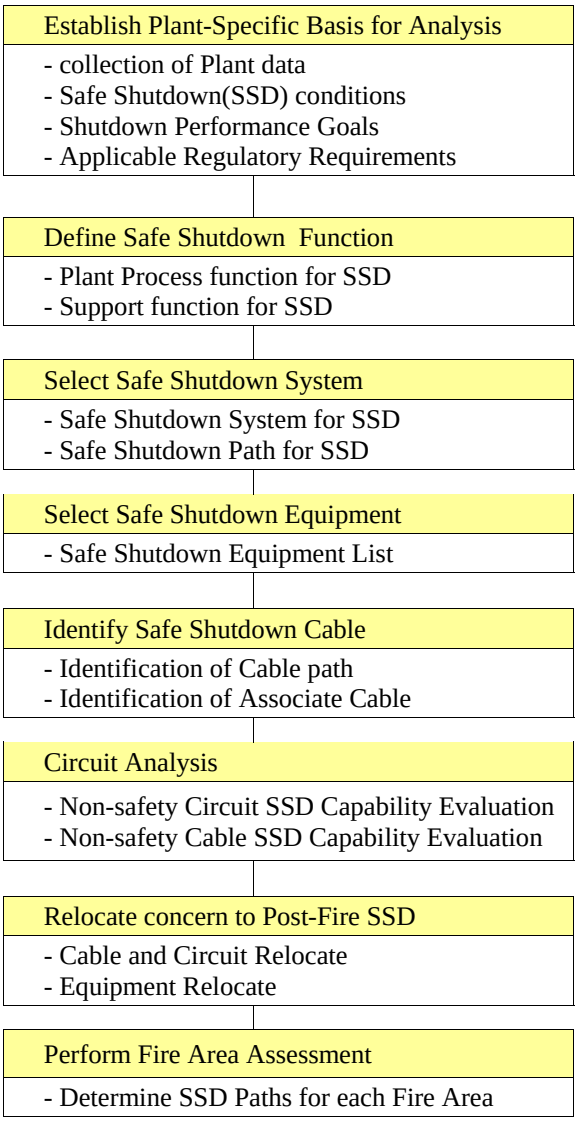

Fig.1. Overview of the Post-Fire Safe-Shutdown Analysis Process

3) Select Safe Shutdown Systems

This step identifies systems capable of accomplishing the required shutdown functions.

The safe shutdown systems are listed in table.1 which are grouped by Safe Shutdown Path A and B for CANDU [3] [4].

4) Select Safe Shutdown Equipments

The step identifies the equipments necessary for the identified systems at step 3) to perform their shutdown functions using Design Manual, Design Guide, FSAR, and Fire Hazard Assessment Report and makes Safe Shutdown Equipment List(fig.2).

Table. 1 Safety Shutdown Systems

Function	System	
	Safe Shutdown Path A	**Safe Shutdown Path B**
Reactor Shutdown	Shutdown System 1	Shutdown System 2
Decay Heat Removal	Volume and Pressure Control System	High Pressure Emergency Core Cooling System
	Atmospheric Steam Discharge Valves	Main Steam Safety Valves
	Auxiliary Feed Water System Shutdown Cooling System	Emergency Water System
Monitoring	Main Control Room	Secondary Control Area
Barrier to Fission of Product Release	Heat Transport System	Containment Isolation System
	Moderator System	
	Reactor Auxiliary System	
Support Services	General Class Ⅰ, Ⅱ, Ⅲ	Emergency Power Supply System
	Recirculated Cooling Water System Raw Service Water	Emergency Water System
	Instrument Air System	Auxiliary Air Tank

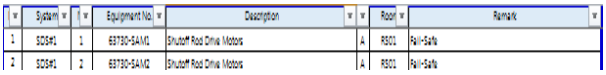

Fig.2. Identify Safe Shutdown Equipment List

5) Identify Safe Shut Down Cable

The step identifies the cable path from start to destination of the equipments necessary for the identified systems using cable pull sheet, Rout Description Report, Raceway Cable Content, General Arrangement diagram, and Electric Diagram.

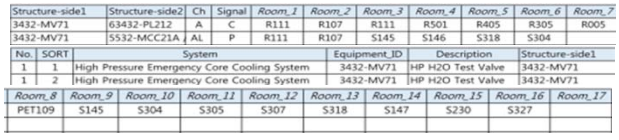

Fig.3. Identify Safe Shutdown Cable

6) Circuit Analysis

For the required component, all circuits (cables) that are needed to ensure proper operation or could cause mal-operation/undesired actuation must be identified.

If a common power source is electrically protected from the circuit of concern by coordinated breakers, fuses, or similar devices of the shutdown equipment and the power source would be identified by coordination of breakers.

A common enclosure with shutdown cables and cause cable fire by suitably sized circuit breakers, fuses, or would cause fire propagate into the common enclosure. This step would be identified by coordination of breakers, penetration seals and fire stops.

A cable damage induced by a fire can cause equipment of which spurious operation or mal-operation may affect the shutdown capability. It is possible to achieve safe shutdown during a fire event at Secondary Control Area in CANDU.

Multiple High-Impedance Fault[MHIF] is a trip of the individual breakers at not sufficient magnitude, if the cumulative effect causes the upstream feeder breaker to trip at a coordination problem. But there is no effect by MHIF[5].

7) Relocate concern to Post-Fire SSD

This step identifies plant process and support functions which should be accomplished to achieve and maintain hot and cold shutdown conditions defined.

The equipment needed to ensure the proper operation of each path should be identified and documented in the Safe Shutdown Equipment List.

8) Perform Fire Area Assessment

This step must demonstrate that one train of equipment used to achieve and maintain hot shutdown conditions remains unaffected by a fire.

3. Conclusions

The purpose of the Post-Fire SSA process is an evaluation process during a fire at NPPs. At this study, the process was conceptually adopted for control room complex of CANDU NPPs. The Core Damage Frequency of the Reactor will be evaluated more accurately if the SSA is adopted adequately at a fire.

REFERENCES

[1] Knowledge Base for Post-Fire Safe-Shutdown Analysis, NUREG-1778, Jan 2004.
[2] Fire Protection for CANDU Nuclear Power Plants, CAN/CSA-N293-M87, CSA, July 1987.
[3] Wolsong unit 3&4 Final Safety Analysis Report .
[4] Wolsong unit 3&4 Fire Hazard Assessment Report, 2012 .
5] Guidence for Post-Fire Safe-Shutdown Analysis, NEI 00-01, Rev 3, Oct 2011.