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Identification of Errors of Commission for the Full Power Operation

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1. Introduction

Errors of Commission (EOCs) are human actions which are not required from the system point of view and aggravate the scenario evolution in Probabilistic Safety Assessments (PSAs) [1]. Interest in EOCs has been increased after the TMI-2 accident where EOCs contributed to the evolution of the accident [2]. It gives the lesson that an EOC can let the event worse, then leading to the severe accident. It is also reported that EOCs are an important contributor to the core damage frequency (CDF) [3].

The need to consider EOCs in PSAs has been recognized by many studies [4, 5] as well as the regulation [6]. However, up to now, modeling of EOCs has generally been beyond the scope of PSA.

Some methods for the human reliability analysis (HRA) have suggested approaches to find the EOCs such as ATHEANA [7], MDTA [8], GRS method [9], CESA [10], Borssele screening methodology [11], MERMOS [12] and CREAM [13]. Among them, CESA is a method which has a formalized way for scenario identification and prioritization. The CESA can also identify risk-significant situations with a potential for EOCs in a predictive analysis.

This study aims at finding EOCs and potential risk factors caused by EOCs for the HRA of APR1400. This study selects initial events which highly contribute to the CDF in the APR1400. Then, potential EOCs in those initiating events are identified through the CESA method.

2. Overview of CESA Method

The CESA's process to identify EOCs complies with a scheme of action-system-scenario. Once a set of actions is defined by their consequences in terms of specific system states, two stages of screening become applicable. First, it is possible to screen on the basis of system failure importance measures, since the links between actions and system failures are deterministic. For a precisely defined action it can be determined explicitly whether it would result in a top or basic event of fault tree. Second, it is possible to screen on the basis of scenario frequencies, since the links between system failures and scenarios are deterministic as well. It can be determined explicitly in which event sequences a given system failure is modeled. This link points to relatively likely scenarios in which an action may cause an important system failure.

Method Steps 1-3 in Fig.1 serve the implementation of the CESA's search scheme, i.e., identification of final EOCs. On the basis of emergency operating procedures (EOPs) and related practices (e.g., with respect to manipulations associated with a procedural task), possible actions are selected and cataloged in Step 1. The result is a plausible set of intervention options (i.e., credible possibilities for human-induced changes of system states).

Step 2 deals with the identification of system failures (or degradations) that may result from these actions. Prioritization of system failures is mainly performed on the basis of the importance measures of the PSA top or basic events for these system failures. It is recommended to use the risk achievement worth (RAW) for this purpose. For instance, the identification may focus on the PSA top (or basic) events with RAW>10. Each combination of a PSA top or basic event with a procedural action (that would contribute to a failure state) defines an EOC event, i.e., an operator action that may contribute to a system failure in some-at this point unspecified-scenarios.

On the basis of the accident sequences in the original PSA model, the scenarios in which an EOC event may occur are identified in Step 3. It is recommended to focus on event sequences with a relatively high frequency. Event sequences that have similar performance conditions are grouped, and each group is defined as a scenario with the opportunity of the EOC event in question. The combination of an EOC event with a group of similar event sequences defines a final EOC, i.e., an operator action that contributes to a system failure in a specific scenario. At this point, the specific scenario evolution and personnel responses that lead to the performance of the inappropriate action have not been determined. For each final EOC, the procedural decision points and the scenario conditions corresponding to the branching criteria are analyzed, in order to identify the EOC paths.

Table I. An example of cataloged actions for SBO

Step No.	Step title	Instruction			Contingency		
		Action	Object	System	Action	Object	System
6	RCS Tavg Control	Open	MSADV	Main Steam	Verify	MSSV	Main Steam
		Check	MSADV	Main Steam			
		Close	Isolation Valve of stuck-open	Main Steam			
7	Maintaining SG Level	Operate	Main feedwater system or auxiliary feedwater system	Feedwater System			
8	Opening Breakers Which Are Connected to the Lost AC Bus	Verify	All supply breakers and feedbreakers	4.16kV Class – 1E System	Open	All supply breakers and feed breakers of 4.16kV and 13.8 kV AC buses which are not energized	4.16kV Class-1E System
9	Restoring C-1 E 4.16kV Bus	Start	EDG	4.16kV Class – 1E System	Identify and Take actions to restore	The cause of C-1E 4.16kV AC bus restoration failure	4.16kV Class-1E System

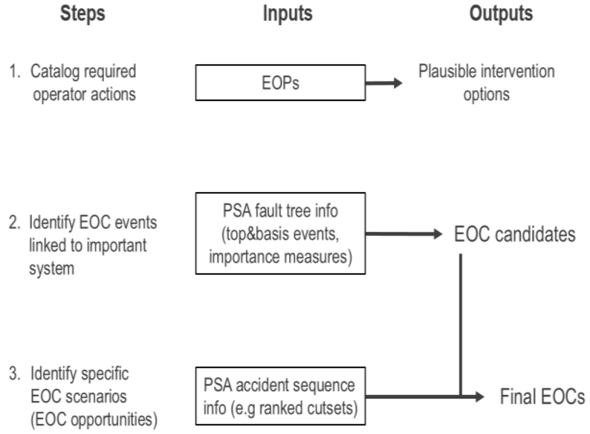

Fig. 1. Flow chart of the EOC Identification steps of CESA [14]

3. Identification EOCs for the full power operation of APR1400

This study applied the CESA method to identify potential EOCs for the PSA of APR1400 in the full power operation. Total eight initiating events that contribute to about 90% of CDFs have been selected, i.e., Station Blackout (SBO), Small Break Loss of Coolant Accident (SBLOCA), Middle Break Loss of Coolant Accident (MBLOCA), Large Break Loss of Coolant Accident (LBLOCA), Interface System Loss of Coolant Accident (ISLOCA), Loss of All Feedwater (LOAF), General Transient (GTRN), and Steam Generator Tube Rupture (SGTR). The detail of results is as follows.

3.1 Catalog key actions

Operator's actions instructed in the EOPs are cataloged and tabulated. All the operator's actions in five EOPs are parsed based on the actions, objects, and systems, as shown in Table I.

3.2 Define EOCs event linked to important actions

At this step, basic events with RAW>10, i.e., total 173 events, are selected to screen the important systems and identify the failure states. Then, the systems and failure states are compared with the cataloged actions which is the result of Step 1. The combination of them results in the EOC candidates. An EOC candidate refers to the operator's actions in the EOP that contribute to the failure of important systems. Table II presents the results of Step 2.

3.3 Identify specific scenarios (EOC opportunities)

This step identifies the final EOCs through the review of accident sequences. This step selects top 1,000 accident sequences with the highest frequency of PSA result and verifies whether EOC candidates may contributes to the evolution of accident sequences. Then, EOC candidates that do not contribute to the evolution of important accident sequences are screened out. As a result, the final EOCs are identified, as shown in Table III.

4. Conclusions

This study presented a process of searching the EOCs for the full power operation of APR1400 in eight initiating events which contribute to about 90% of CDFs with CESA method. As a result, twenty final EOCs in eight initiating events are identified.

Table II: The result of Step2

	SBO	LOCA				SGTR	LOFW	GTRN
		SBLOCA	MBLOCA	LBLOCA	ISLOCA			
CDF Contribution (Total: 90.3%)	60.8%	16.8%	3.3%	1.3%	2.6%	2.9%	0.9%	1.7%
EOC Candidates	• Close SCS inlet valves • Open SI pump injection valves • Line up the valves • Start SI Pumps • Restart SI pumps • Close MSIVs • Open MSADV • Manipulate SBCS valves or MSADV • Operate SBCS valves, MSADVs • Open the MSIV bypass valves • Open SBCS valves • Open the isolation valve (IA-V017) • Operate auxiliary feedwater system • Open supply breakers of all unnecessary DC loads • Start N-1E diesel generator • Energize C-1E AC bus	• Actuate SIAS, CIAS • Actuate CSAS • Reset SIAS to CSP • Reset SIAS and CIAS • Start SI pumps • Control SI flow as necessary • Control SI flow or Stop SI Pump • Restart SI pumps • Maintain PZR level within 30-70% • Start one RCP in the operating loop • Start one RCP in the opposite loop • Operate charging pumps or SI pumps • Stop one SI pump at a time • Operate SI Pumps • Open SI hot leg injection isolation valves • Line up the valves to ensure that the LTOP system is operable • Close all MSIVs • Open the MSIV bypass valves • Open SBCS valves • Open MSADV • Operate SBCS valves or MSADV • Open SI hot leg injection isolation valves • Close the direct vessel injection isolation valves for SI pumps • Close the isolation valve of the stuck-open MSADV • Maintain SG levels within 25~88% (WR) • Feed and bleed the suspect steam generator using the feedwater system • Operate main feedwater system or auxiliary feedwater system • Stop the affected RCP(s) • Close CIAS interlock containment isolation valves				• Actuate SIAS • Start SI pumps • Control or stop the SI flow or one SI pump at a time • Operate Charging pumps and SI pumps • Line up the valves to ensure that the LTOP system is operable • Close MSIVs of SG1 • Close MSIV bypass isolation valves of SG1 • Decide the sound (or least affected) SG 1 is wrongly isolated • Close all MSIVs • Operate SBCS valves using the sound (or least affected) SG 2 • Operate MSADV of the sound SG 2 • Operate SBCS valve(s) using the isolated SG 1 • Open MSIVs • Open MSADV • Open MSIV bypass valves • Release the isolated SG steam using SBCS valves • Close MSIV bypass valves • Open all of the AX-V1623/1624/1627 • Open all of the AX-V1208/1626/1623/1624 • Feed and bleed the suspect steam generator • Maintain SG levels within 25~88% (WR)	• Reset SIAS and CIAS • Control or stop the SI flow or one SI pump at a time • Operate Charging pumps and SI pumps • Restart SI pumps • Line up the valves to ensure that the LTOP system is operable • Close all MSIVs • Close the isolation valve of the stuck-open MSADV • Operate SBCS valves or MSADVs • Open MSADV • Feed and bleed the suspect steam generator using the feedwater system	• Operate SBCS valves or MSADVs

Table III: Final EOCs

	SBO	LOCA				SGTR	LOFW	GTRN
		SBLOCA	MBLOCA	LBLOCA	ISLOCA			
Final EOCs	Operate main feedwater system or auxiliary feedwater system Open supply breakers of all unnecessary DC loads Operate SBCS valves, MSADVs	Control or Stop SI Pump Operate charging pumps or SI pumps Restart SI pumps are necessary Operate SI Pumps	Control or Stop SI Pump Operate charging pumps or SI pumps Restart SI pumps are necessary Operate SI Pumps	Close the direct vessel injection isolation valves for SI pumps		Close the MSADV Control or stop SI flow or one SI pump Operate charging pump or SI pump Feed and bleed the suspect steam generator	Control or stop SI flow or pump Operate charging pumps or SI pumps Feed and bleed the suspect steam generator	Operate SBCS valves or MSADVs

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