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Impact of Applying Flood Mitigating Actions to Internal Flooding Scenarios

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1. Introduction

Internal flooding is all floods originating within the plant boundary. The overall objective of Internal Flood Probabilistic Safety Analysis (IFPSA) is to ensure that the impact of internal flood as the cause of either an accident or a system failure is evaluated. IFPSA didn't consider flood mitigating actions in the past. To ensure the more realistic evaluation for the IFPSA, it is necessary to include operator actions isolating the flood source. The flood mitigating actions are taken by Main Control Room (MCR) operators as well as by auxiliary operators out in the plant to terminate the flood. By applying operator actions that have the ability to terminate the flood impacts and propagation to other areas, it will reduce the impact on the accident initiation or mitigation equipment. These actions may include closing a valve to isolate a leak, or shutting down pumps to terminate flow. This study identifies and quantifies the reliability of the human actions based on current plant procedures, training, and actual practice and how shutting down pumps or closing a valves locally operator action affects conditional core damage probability (CCDP).

2. Methods and Results

2.1 Shutting down pumps or closing a valve locally operator action analysis

2.1.1. Selection of operator action

The instrumentation used for the identification of the flooding condition is primarily annunciators in the MCR. Fire protection pipe break among unlimited flood sources is a typical scenario. For example, there are fire protection alarms and sump level alarms in the MCR that would indicate fire protection system pipe ruptures in different locations of the plant not in case of fire. Additionally, there are alternate indications such as system pressure, flow and level indications that can be used by operators for identification of the flood source system. In case of fire protection pipe ruptures, the operator action to terminate flood may be credited with flood mitigating actions [1].

2.1.2. Information for operator action analysis

A Human Reliability Analysis (HRA) of flood response actions involves identifying relevant alarms, indications, procedures and communication protocols. The likelihood of successful manual isolation depends on means of detecting the piping system failure, successful diagnosis, availability and accessibility of the isolation equipment, the amount of time available to prevent specific consequences and operator performance.

A HRA is performed using the methods in HCR/ORE and THERP with consideration of flood conditions and Performance Shaping Factors (PSFs) [2].

2.1.3. Flood mitigation operator action analysis

There are several flood mitigation Human Failure Events (HFEs) identified. These are operator flood mitigation actions to isolate the postulated floods before they propagate to other areas or quadrants. One of the several flood mitigation HFEs performs detail analysis in this study. It is assumed that failure in isolation of the fire protection system flood event in 75 minutes would cause a major inter-quadrant propagation. There are valves in the yard which can each isolate an auxiliary building fire protection system header. These valves should be readily accessible regardless of where the break in fire protection is located.

Data to calculate operator action failure probability are as follows.

- Initial Cue: Sump level alarms
- Recovery Cue: Fire protection alarms
- System time window: 75 minutes
- Time delay: 10 minutes
- Cognition time: 5 minutes
- Execution time: 30 minutes

The plant is in full power operation before the flood initiating events occurred. The initiating event induced by fire protection pipe break in the auxiliary building. Operators will receive sump level alarms and fire protection alarms in the MCR that would indicate a fire protection pipe break and guides them to enter a flood or an abnormal procedure. Operators will trip the fire pumps or close a valve locally in yard.

Table 1. Summary of cognition analysis of HFE

Sigma Table				
Plant Type	Response Type	LB	Sigma	UB
PWR	CP1	0.26	0.57	0.88
	CP2	0.07	0.38	0.69
	CP3		0.77	
Sigma:	5.70E-01			
HEP:	3.20E-04			

Table 2. Summary of execution analysis of HFE

<table>
<tr><td colspan="4">Execution Unrecovered</td></tr>
<tr><td colspan="4">Step 1</td></tr>
<tr><td colspan="2">Insturction</td><td colspan="2">Close the valve locally</td></tr>
<tr><td colspan="2">Location</td><td colspan="2">Auxiliary Building</td></tr>
<tr><td rowspan="8">THERP</td><td>Error Type</td><td colspan="2">EOM</td></tr>
<tr><td>Table</td><td colspan="2">20-7b</td></tr>
<tr><td>Item</td><td colspan="2">1</td></tr>
<tr><td>HEP</td><td colspan="2">4.30E-04</td></tr>
<tr><td>Error Type</td><td colspan="2">EOC</td></tr>
<tr><td>Table</td><td colspan="2">20-13</td></tr>
<tr><td>Item</td><td colspan="2">1</td></tr>
<tr><td>HEP</td><td colspan="2">1.30E-03</td></tr>
<tr><td colspan="2">Stress Factor</td><td colspan="2">Moderate</td></tr>
<tr><td colspan="2">Total Step HEP</td><td colspan="2">3.46E-03</td></tr>
<tr><td colspan="4">Step 2</td></tr>
<tr><td colspan="2">Insturction</td><td colspan="2">Verification step</td></tr>
<tr><td colspan="2">Location</td><td colspan="2">MCR</td></tr>
<tr><td rowspan="4">THERP</td><td>Error Type</td><td colspan="2">EOM</td></tr>
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<tr><td colspan="2">Stress Factor</td><td colspan="2">Moderate</td></tr>
<tr><td colspan="2">Total Step HEP</td><td colspan="2">8.60E-04</td></tr>
<tr><td colspan="4">Execution Recovered</td></tr>
<tr><td>Critical Step No.</td><td>Step 1</td><td></td><td rowspan="2">Total Unrecovered:</td></tr>
<tr><td>Recovery Step No.</td><td></td><td>Step 2</td></tr>
<tr><td>HEP (Crit)</td><td>3.46E-03</td><td></td><td>3.46E-03</td></tr>
<tr><td>HEP (Rec)</td><td></td><td>8.60E-04</td><td rowspan="3">Total Recovered:</td></tr>
<tr><td>Dep.</td><td></td><td>LD</td></tr>
<tr><td>Cond. HEP (Rec)</td><td></td><td>5.08E-02</td></tr>
<tr><td>Total for Step</td><td>1.76E-04</td><td></td><td>1.76E-04</td></tr>
</table>

Table 3. Result of flood mitigation operator action

Item	Data
Operator Action	Operators trip the fire pumps or close a valve locally
HEPcog (mean)	3.20E-04
HEPexe (mean)	1.76E-04
Total HEP (mean)	4.96E-04
Error Factor (EF)	10

2.2 Flood mitigation operator action applying to flood scenarios

The potential flood sources in the flood scenario consist of a variety of pipes located in the general access area of second floor quadrant B. The water from the fire protection pipe break begins to rise and flow spreads through door gaps and drain. When the water level reaches 0.125 ft. in the flood initiating area, the water propagates to first floor quadrant B through emergency overflow line.

The flooding mitigation action is used in this flooding scenario. The operator action requires preventing flooding from an unlimited source to reach a level in the lowest elevation of the initiating quadrant which would threaten the barrier between quadrants.

2.3 Comparison of flood mitigation operator actions applying result

The biggest difference is the propagation path. The flood sources in the first scenario which succeeds flooding mitigation action propagate only to initiating quadrant because the barrier between quadrants is not failed due to the operator actions. The success of the operator actions prevents the flood sources from rising so that the barrier is not damaged. However, the other scenario which fails flooding mitigation action propagates to adjacent quadrant because the barrier between quadrants is failed by water pressure.

Table 4. Comparison of success or failure of flood mitigation operator actions

Scenario	First Scenario	Second Scenario
Flood frequency	2.73E-04	2.73E-04
Initiating Event	GTRN	GTRN
CCDP	6.28E-06	6.29E-06
Flood mitigation HEP	-	4.96E-04
CDF	1.71E-09	8.52E-13

3. Conclusions

This study describes the impact with applying flood mitigation operator action to flood scenario. The CCDP of flood scenario mainly depend on which equipment is failed. In case of flood accidents, failure of flood mitigation action causes more equipment to be failed. Even though it may result in higher CCDP, applying the operator action make CDF don't have big impact or obtain the low frequency. Because probability of flood mitigation operator action failure is about 1E-05 and CDF result from CCDP multiplied by HEP and initiating frequency.

REFERENCES

[1] EPRI TR-1019194, Guidelines for Performance of Internal Flooding Probabilistic Risk Assessment, December 2009.

[2] EPRI TR-100259, An Approach to the Analysis of Operator Actions in Probabilistic Risk Assessment, June 1992.

[3] NUREG/CR-1278, Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, August 1983.