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Mitigating Capability Analysis during LOCA for Korean Standard Nuclear Power Plants in Containment Integrity

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1. Introduction

The objective of this paper is to establish Containment spray operational technical bases for the typical Korean Standard Nuclear Power plants (Ulchin units 3&4) by modeling the plant, and analyzing a loss of coolant accident (LOCA) using the MAAP code. The severe accident phenomena at nuclear power plants have large uncertainties. For the integrity of the reactor vessel and containment safety against severe accidents, it is essential to understand severe accident sequences and to assess the accident progression accurately by computer codes. Furthermore, it is important to attain the capability to analyze a advanced nuclear reactor design for a severe accident prevention and mitigation.

2. Analyses Results and Application

In this section the methodology of how to model the plant, and analyze loss of coolant accident using tool and results in managing accidents occurring in a nuclear power plant is described.

2.1 LOCA Analyses

This study shows the data preparation as well as accident assessment results for a LOCA using the MAAP code. [1] A LOCA event is defined as random RCS break inside containment with an effective break area ranging from small (0.02 ft^2) to large (0.8 ft^2). According to the general assumptions of this analysis, it is assumed that the break occurs in the cold leg downstream of the RCP. In regionalizing and modeling the containment, the containment is divided into 5 regions. Flow path between regions are labeled by the constituents (steam, water, hydrogen, non-condensable gases and corium). The reactor coolant system (RCS) is divided into 15 nodes and the core is composed of 56 nodes, that is, 4 radial zones and 14 axial zones. When a LOCA occurs, the RCS is rapidly depressurized. The reactor trip signal is generated by a low pressurizer pressure or high containment pressure. However, the nuclear reaction is quick to cause a shutdown due to a voiding in the core region even if the control rods are not inserted. The Low Pressure Safety Injection system cannot be credited for a inventory control. Instead, High Pressure Safety Injection pumps deliver water from the refueling water tank to the RCS cold legs.

2.2 Mitigating Analyses of Severe Accident Sequences

-Base Case:

Accident analyses are also investigated to find out how much containment spray is effective to mitigate severe accident progresses in terms of containment integrity. For nominal base case of large LOCA (LLOCA15) without spray, containment vessel failure is about 72 hrs. When spray operation is considered for mitigating the accident progression, the containment vessel failure time is not occurred until 259,200 seconds (72 hrs as mission time required) after a LOCA is initiated. This analysis ensures that the spray capability as a recovery action is useful for accident management and mitigation.

- Mitigating Effect Case:

Though some sensitivity runs were done in the PSA study, they show the effect of safety parameters on accident progression systematically. In terms of accident management, this information can be useful to deal with an accident progression systematically as the following examples of parameters for the base case and the sensitivity runs for a LOCA sequence.

1) Spray Effect Sensitivity:
-Spray Pump on / off

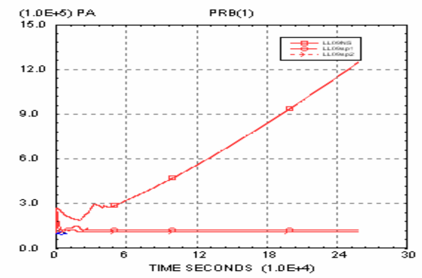

Figure 1. Containment Pressure on Number of Spray (0/1/2) In case of Large LOCA

2) Safety Injection Effect:
- HPSI Pump on / off

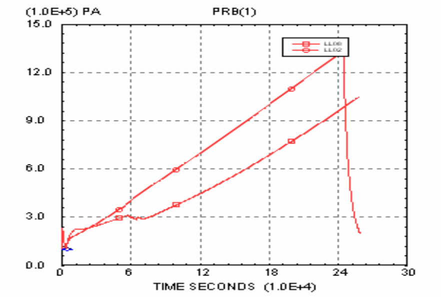

Figure 2. Containment Pressure on Number of HPSI (0/1/2) In case of Large LOCA

3) Charging Flow Effect:
- Pump Flow

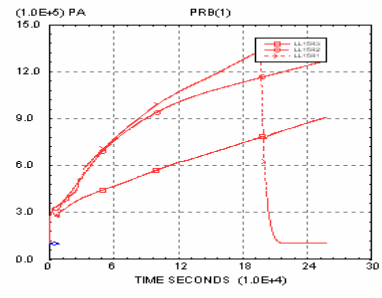

Figure 3. Containment Pressure on Charging Flow Rate In case of Large LOCA (0, 88, 132 gpm)

2.3 Other Mitigating Effects

- Break Effect Sensitivity :
  Break Location (Cold-leg, Hot-leg)
  Break Size (0.4 ,0.8 ,10.02 ft2)

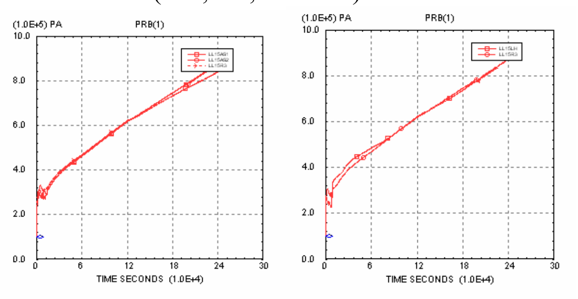

Figure 4. Containment Pressure of Break Location and Size In case of Large LOCA

For these cases of break sizes and locations, some mitigating analyses run have done in this study. They show how much the break related parameters affect accident progression in containment. In terms of accident management, these effects are not as significant as other previous analyzed parameters are in the end.

- *Small / Medium LOCA Sequence based Analysis*

For other LOCA sequences, Containment Pressure can be analyzed for small and medium LOCA same as that of large LOCA.

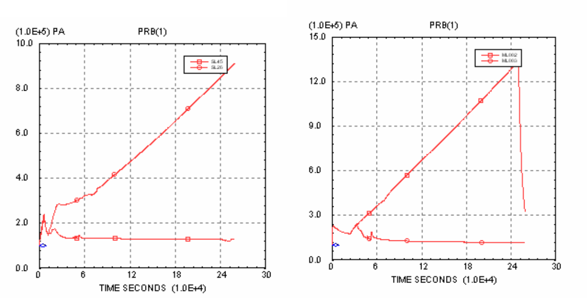

Figure 5. Containment Pressure on effect of Spray (0/1) of Small LOCA (26,45) & Medium LOCA(2,3)

2.4 Display of Mitigating Path

The suggested mitigating paths based on previous research results can be checked by monitoring the plant status using display support system such as the Severe Accident Training Simulator (SATS) [2].The path monitor checks the status of the safety system selected by the maintenance status and displays the optimal mitigating path based on each component with a mimic display of a system drawing. An example display of an optimal success path selected from the integrated reliability rules is shown in in Figure 6.

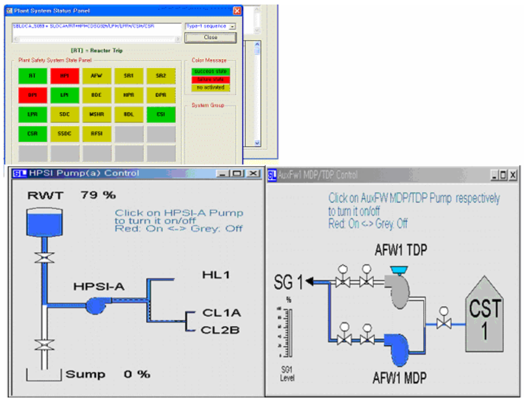

Figure 6. Sample of a Mitigating Path in Computer Monitor

3. Conclusion

Mitigating effects for containment integrity have been studied through a set of LOCA whose elements were a plant's specific status, scenarios and parameters. If containment spray system fails with a successful safety injection for a large, medium and small LOCA, the containment pressure reaches to the containment failure limit. Otherwise, if the spray system is available, the containment pressure is relatively low regardless of the safety injection. Mitigating effect analyses showed how much various accident status (break size & location) and safety parameters (safety injection) evidently affected accident progression.

Acknowledgements

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REFERENCES

[1] USNRC, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants", NUREG-1150, ,1989
[2] K. R. Kim, "Development of a Severe Accident Training Simulator: SATS," 2002 ANS Annual Meeting, Hollywood, FL , June (2002).