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Severe Accident Management Scheme Using Accident Scenario Event Tree

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1. Introduction

Since the Three Mile Island (TMI) accident, the importance of accident management in nuclear power plants has increased. Many countries have focused on understanding severe accidents, in order to identify ways to further improve the safety of the plants [1]. It has been recognized that plant-specific probabilistic safety assessments (PSA) can be beneficial in understanding plant-specific vulnerabilities of severe accidents [2].

The objectives of this paper are to identify plant response and vulnerabilities via analyzing the PSA quantified results and to set up a framework for an accident management program based on these analysis results.

2. Methods and Results

In this section the methodology of how to use PSA results in managing accidents occurring in a nuclear power plant is described. In particular, we are mainly interested in severe accidents because less serious accidents usually evolve more rapidly at the systems level compared to such severe accidents that may involve core damage to some extent.

2.1 Identification of Plant Damage State

Although level-1 PSA may be somewhat useful for certain accident types, the analysis results of level-2 PSA would be more helpful in managing severe accidents. Hence, in this study we focused on level-2 PSA to develop how to use PSA results for accident management.

Level-2 PSA covers containment performance analysis and source term analysis. In order to connect the results of level-1 PSA to level-2 PSA, plant damage states (PDSs) are defined and each level-1 sequence is grouped into an appropriate PDS. For each PDS, the accident phenomena are analyzed together with the analysis of containment performance. The failure probability of the containment is then evaluated for all the sequences leading to core damage. Plant-specific source terms are next evaluated for those accident sequences which represent the characteristic source term categories [3].

2.2 Identification of CET Heading Controllability

Modeling complicated containment events can be simplified by the use of decomposition event trees (DETs). DETs offer advantages by allowing the use of a generalized containment event tree (CET) logic structure for most PDSs while keeping the size of the CET reasonable for scrutability and understanding. The PDS-specific quantification and additional event phenomenology are then contained in the DETs.

The basic considerations in the construction of a DET are:

1) The last event in the DET is the same event heading as in the CET. Each possible branch pathway shown in the CET for this event must also exist in the DET. After the DET is quantified, the end point probabilities for similar branches in the last event are summed together and these summed probabilities are passed back into the CET as CET branch probabilities.

2) The selected sub-events can be quantified with available data or analyses.

3) All dependencies in the sub-events on PDS conditions and prior CET branch point decisions can be rigorously treated.

The controllability of CET top events or sub-events of their corresponding DET is examined in this step to identify controllable events which will be considered later in prioritizing the CET paths.

2.3 Identification of Feasible Success Paths

Once the controllability of the CET top events and the DET sub-events are examined, then feasible CET paths in view of the event controllability and current plant state are identified. These success paths also represent the phenomena, such as ex-vessel steam explosion or hydrogen burning.

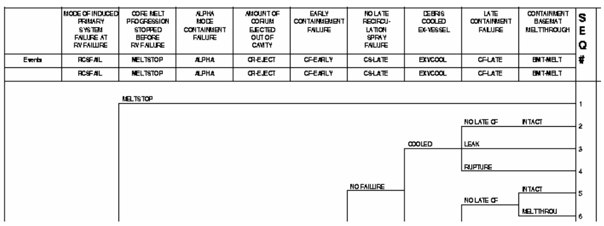

Figure 1. CET Grouping for PDSs 3 ~ 42

The feasible CET paths should be identified from the CET in Figure 1. in this study, the aim of accident management is placed on minimizing the likelihood of early containment failure.

The phenomenological branch point probability should be one or zero (i.e., occurrence or non-occurrence). However, because of the current lack of knowledge regarding the phenomenon, it is not possible to identify the correct branch. The branch point probabilities that are assigned must therefore represent the analyst's degree of belief that the accident will progress along the branch.

2.4 Calculation of Conditional Probability of Early Containment Failure

Early containment failure is one of the most severe cases of plant containment failure modes in terms of radionuclides release. Thus, even though early containment failure is found to take place relatively infrequently, it should be given special attention in accident management. The probability of containment failure and its failure mode is calculated using the containment fragility curve developed by a domain expert.

The early containment failure may occur as a result of either rupture or leakage of containment. Thus, the three modes of early containment failure, namely rupture, leakage, or no early containment failure, can be identified using containment failure event tree. Among these, the rupture failure is determined to be the most dominant contributor to the early containment failure.

The conditional probability of early containment failure can be calculated by multiplying the branch probabilities of each feasible CET path, as is done in a typical event tree quantification.

2.5 Suggested Path Monitoring

The suggested paths can be checked by monitoring the plant status with the SAMAT system [4]. The support system for decision-making with severe accident management provides plant parameters to monitor plant status. The path monitor checks the status of the safety system selected by the maintenance status and displays an optimal success path based on each component with a mimic display of the systems drawings. An example display of an optimal success path selected from the integrated reliability rules is shown in Figure 2 for a typical electrical system. Eventually, the operator will be supported by this generation of success path sets to restore the plant. Then, the operator can make an appropriate decision without ambiguity and complexity.

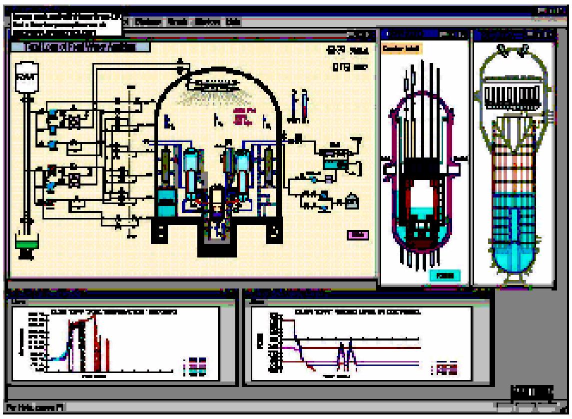

Figure 2. Display of Optimal Success Path for LOOP in Computer Monitor

3. Conclusion

The increased sophistication of PSA models and the descriptions of risk results offer the potential for improving the decision-making process. In this study, we investigated methods to utilize the plant-specific PSA results effectively for decision-making in managing accidents in the plant.

In particular, our approach of applying PSA results to accident management is based on back-end analyse, i.e., level-2 PSA results, because the current emergency operating procedures (EOPs) do not properly cover the severe accident regime involving core damage. The results of back-end analyses help to identify plant vulnerabilities and appropriate plant responses to a specific challenge [5].

Acknowledgements

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