A Method for Modeling Plant Operating Status in PHWRs

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1. Introduction

The development of risk monitoring technology, which is the basic part for estimating the optimum duration, is required for getting economic benefits by optimizing the duration of the preventive maintenance as well as for assuring safety of a nuclear power plant. For the development of risk monitoring technology, it is inevitable to model Plant Operating Status (POS) in the first place. In this study, a tool for modeling the POS is introduced.

2. Modeling Method using Decision Trees

Decision trees are the tool for the framework to determine quantitative evaluations of potential transients and accidents with various uncertainties. The decision trees are also typically used to determine safety function defense-in-depth, which can estimate the decrease effect resulted from maintaining components. With the flexibility of decision tree design, qualitative evaluations using decision trees fulfill the requirements for defense-in depth evaluations [4].

The decision trees are a graphical and mathematical representation of a decision problem. They are connected trees with two types of nodes (decision, chance) and two types of branches (probabilistic, alternative). The chance nodes have two basic types of uncertainty, which are due to stochastic variability and due to inadequate knowledge or data (state-of-knowledge uncertainty). Some of the chance nodes represent phenomenological events that are deterministic in nature, i.e., they will always occur or never occur given the states of the predecessor nodes.

Decision trees have two significant drawbacks. First, decision trees grow exponentially with problem size. Second, decision trees have no provisions for the explicit representation of the probabilistic dependency between node variables. In spite of these drawbacks, the reason decision trees are selected is an advantage of this tool, which is the explicit representation of the decision structure, which shows the decision maker the value of each possible outcome that is all of the possible scenarios that could occur.

Once constructed, the decision trees can generally be quantified and solved in order to evaluate decision problems. To solve the decision trees means to compute the expected values associated with the attributes of the value node, given the possible decisions. The decision trees utilize the concept of 'rollback' to solve a problem. This means starting at the right-hand terminus with the highest expected value of the tree and working back to the current or beginning decision point to determine the decisions that should be made.

3. An example using Decision Trees

Figure 1 shows a case with adverse effects. The lower branch, 'Do nothing', is the risk associated with employment of standard emergency operating procedures. The upper branch, 'Flood cavity', has three chance nodes. The first chance node C1 represents the question of feasibility. The second chance node C2 represents effectiveness. The third chance node C3 represents adverse effects. Note that this last question can also apply to the feasibility issue as well. The branch, 'Flooding not successful', may also lead to the potential adverse effect if the cavity is partially filled with water. [1]

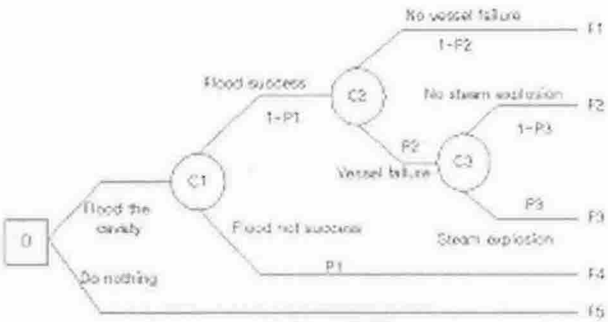

Figure 1. Decision Tree for Cavity Flooding

Early containment failure can be attributed to two phenomena that are direct containment heating and ex-vessel steam explosions. From Reference [3], the following values for the risks (F1) and the probabilities (Pi) are derived :

P1=0.41 : The probability that the option is not effective, given the water is not timely.

P2=0.098 : The probability that the option is not effective, given the water is there in time.

P3=0.5 : The probability of an adverse effect, given water in the cavity.

F1=0 : If there is no vessel failure, the conditional probability of early containment failure, Pecf=0.
F2=0 : If the vessel fails and the melt is quenched, Pecf=0.

F3=0.01 : If the vessel fails and there is an ex-vessel steam explosion, but no direct containment heating, Pecf is reduced.
F4=0.025 If flooding is not successful; same as "Do nothing".
F5=0.025 Given in NUREG-1150 ; 'Do nothing'[2].
Every sample observation contains either the value of 0 or the value of 1 for the occurrence probability. And the fraction of the observations containing the value of 1 is determined by the split fraction that characterizes the state-of-knowledge uncertainty about the occurrence of the event in question. For nodes that model stochastic events, the continuous distribution of the occurrence frequency of the event in question is sampled. Every sample observation then results in a point value of the event occurrence frequency.

4. Conclusions

The decision trees have been introduced as a tool for modeling and assessing POSs (plant operating status) involving maintenance. The decision trees can be used for representing complex relationships that can occur in overhaul periods. It is explicit that the decision structure may directly show the decision maker the value of each possible outcome. This tool can be utilized as the basis for the framework to simulate various malfunctions during overhaul periods as well as to assess the risk during the shut down mode associated with a POS.

REFERENCES

[1] M. Jae, G. Apostolakis, "Sensitivity and Uncertainty Analysis of Accident Management Strategies involving Multiple Decisions," Nuclear Technology, Vol.104, No. 1 (1993)
[2] USNRC, "Severe Accident Risks : An Assessment for Five Nuclear Power Plants," NUREG-1150, Vol. 1&2 (1998)
[3] M. Jae, , G. Apostolakis "The Use of Influence Diagrams for Evaluating Severe Accident Management Strategies in Nuclear Power Plants," Nuclear Technology, Vol. 99, No. 1 (1992).
[4] Leo Shanley, Doug True, "Risk-Informed Decision Making with PARAGON", ERIN Engineering and Research, Texas A&M University, USA (2004)