

Teaching Notes

Operational Reactor Safety Course

Lecture: 11 – Probabilistic Safety Analysis

Objective:

The objective of this lecture is to gain an appreciation of probabilistic risk assessments in design and operation. It is not intended for students to become PRA experts but to understand what PRA is in terms of event and fault trees. NRC use of risk informed decision making is discussed as are safety goals.

Key Points to Bring Out:

<u>Slide number</u>	<u>Points</u>
3-4	Contrast deterministic and probabilistic analysis - key points are that PRAs do not assume systems function with 100% reliability as in deterministic analysis and includes human error. Deterministic analysis attempts to bound system human failures.
5	The purpose of showing this slide is to point out the complex nature of nuclear plants. PRAs need to model all systems that have any influence on the core or heat removal.
6	Review PSA applications noting that the trend in regulatory and design applications - explain what risk informed performance based regulation means.
7	Review history of PRA and why it is a good tool for decision making and design to increase understanding of plant systems and their failure modes.
8-10	Review the basis of the "Farmer Paper" as a methodology for judging acceptable risk results by using credible and incredible accidents.
11-13	Review what goes into a PSA - event and fault trees and how calculated. Summarize historical studies - technology has been in use since 1975 with the Rasmussen Reactor Safety Study.

- 14-15 Review results of the Reactor Safety Study - Wash 1400 - key is that deterministic analysis missed more likely and significant risks.
- 16-17 Begin explaining how a PRA is performed with an explanation of sequence of events diagrams -(judgement of what initiating events may occur and what might happen) - event and fault trees.
- 17 Explain the different types of PRAs - Levels and their functions. Be sure to include a discussion of uncertainties. Remind students that the consequence analysis uses deterministic analysis to predict results under varying conditions postulated. One can not do a PRA without a great deal of deterministic analysis of plant performance to which probabilities of component failures are assigned for a judgement of the likelihood of the event sequence.
- 19-29 Go over a simple example of a pumping system to develop system event trees and fault trees.
- 30 Point out where data comes from for failure rates of components - industry and NRC maintain data bases for component failures - plant experience data is very important for credible PRAs.
- 31 One of the key questions about the use of PRAs is uncertainty. Most PRAs carry uncertainties through the analysis that addresses distribution of failure rates and uncertainties in outcomes of system performance. Key point is uncertainty may dominate results. Confidence levels are typically given based on sampling methodologies.
- 32-36 Explain how the risk is calculated by combining the frequency, time interval and consequences that are summed to assess overall risk of the facility. For a complete risk assessment (all three levels), one must integrate the plant, containment and site model to assess risk to the public.
- 37 An important slide that shows the complete plant risk model - all three levels.
- 38-39 Shown is an example of an ATWS event tree with quantification of frequency and assessment of consequence. Important to go over to have students appreciate the tool. Note the inputs needed to perform the analysis as shown in slide 39. Human performance response is controversial - use of Swain's handbook is the standard reference based on actions and time needed.
- 40-44 Explain definitions of core damage frequency and large early

release frequency which are key indicators of safety of the plant. Point out typical risk contributors in a PWR noting external events are as important as internal (component) failures. Discuss definition of conditional failure probability.

- 45-47 Review shutdown risk -which are not negligible particularly during refueling. This may be surprising to students - 43% of the total risk.
- 48-54 These slides review the NRC's view of risk assessments post the Rasmussen report - key is they walked away from the technology for many years even though the industry continued to perform PRAs on their plants - review results presented to observe variability in core damage frequency. Mention that NRC did eventually require Individual Plant Evaluations - Level 1 PRAs on all plants Mention the use of mean vs. Median results of PRA and confidence limits.
- 55-58 Review NRC safety goals and bases of subsidiary quantitative safety goals.
- 59 A good summary of quantitative safety goals as applied to the three levels of PRAs. Don't forget to include uncertainties as a factor.
- 60-64 Using the United Kingdom's risk tolerance curve, the US evolution of the use of PRA in decision making should be explained. Slide 64 shows how the current Commission is applying risk in regulation.

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