



Nuclear Power Plant Precursor Risk Assessment Using a Dynamic Probabilistic Risk Method

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Presentation Overview

- Motivation
 - Events Assessment Activities at the NRC
 - Challenges
- Description of ADS-IDAC Model
 - Validation
 - Case Study
- Insights and Conclusions

Motivation – Events Assessment

- Accident Sequence Precursor (ASP) Program
 - Identify, document, and rank the operating events that are most likely to lead to inadequate core cooling and severe core damage precursors.
 - By reporting protocols, significant precursors (CCDP or Δ CDP $\geq 1E-3$) are reported annually to the US Congress.
- Significance Determination Process (SDP)
 - Evaluates risk significance of licensee performance deficiency.
 - Categorizes findings in four bins (Green, White, Yellow, and Red).
 - Used to prioritize oversight activities.
- Condition vs. Event Assessment

Motivation – Current Challenges

- Operating events often not explicitly included in plant PRAs.
- PRA success criteria may not represent actual event conditions.
- Complex dependencies between events are not realistically captured in a static fault tree/event tree model.
- Communicating risk.

Motivation – Dynamic PRA

- Dynamic methods can help mitigate a number of these challenges.
 - More realistic modeling of plant response, success criteria, and complex dependencies.
 - Minimizes the use of simplifying assumptions.
 - Supports better communication of risk insights.
- Applying dynamic methods within the event and condition assessment domain can mitigate sequence explosion.

- RELAP5 plant simulation integrated with operator crew model and dynamic PRA scheduler.
 - Discrete Dynamic Event Tree (DDET) approach.
 - Branching events include operator preferences (e.g., decision making style), action execution (e.g., timing), and hardware failures & recovery.

ADS-IDAC Validation

- Calibrated and validated using data derived from international empirical HRA study.
 - Steam generator tube rupture and loss of heat sink.
- Benchmarked against station blackout scenarios described in NUREG-1953.

Case Study – Description

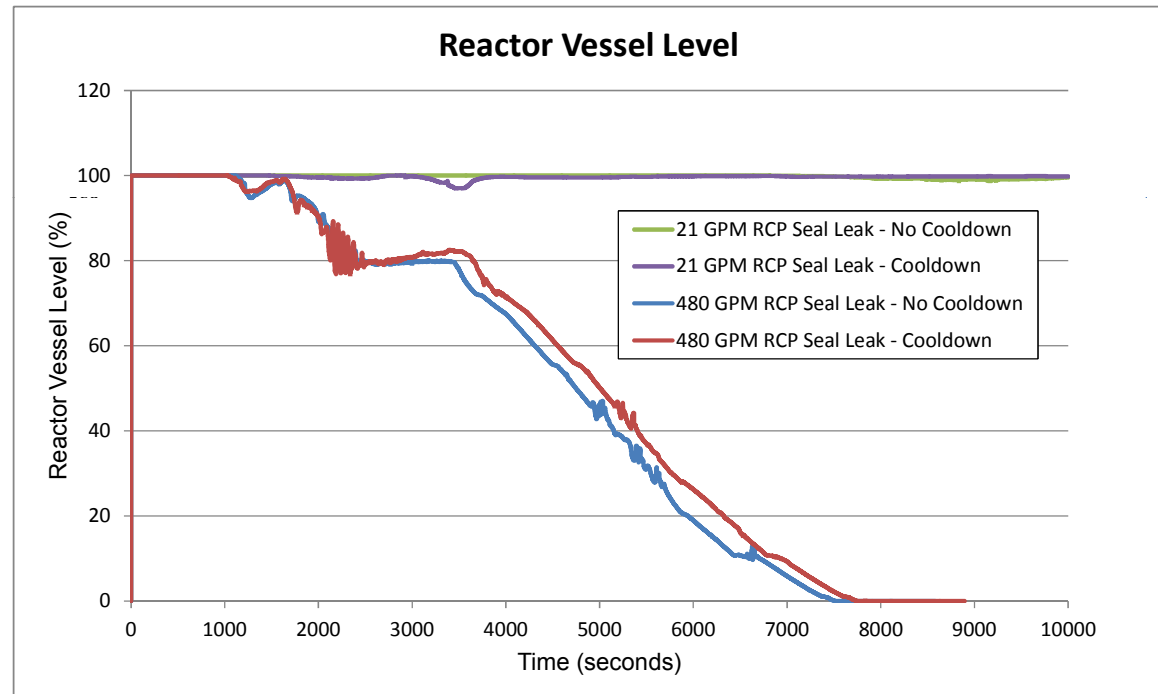
- Robinson (3-Loop Westinghouse PWR)
 - On March 28, 2010, an electrical fire occurred leading to the trip of Reactor Coolant Pump (RCP) B and subsequent reactor trip.
 - Steam plant failures result in rapid reactor coolant system (RCS) cool down.
 - Electrical transient causes loss of RCP seal cooling, RCP seal injection also either unavailable or inadequate.
- Operators successfully recovered seal cooling during the event, but precursor risk arises due to potential for seal failure and consequent loss of coolant.
- Complex event – multiple human errors and equipment failures with subtle dependencies, timing issues, and sequence of actions were all important.

Case Study – Key Issues

- Impact of 480 gpm/RCP seal leak – medium or small break loss of coolant?
- Impact of inadvertent RCS cooldown on operator response.
- Time available prior to core damage with no high-pressure injection.

Case Study – Results & Insights

- Seal Leakage Rate
- RCS Cooldown
- Time Available



Conclusions – Dynamic Approaches

- Dynamic approaches can provide qualitative support for traditional PRA analyses.
- Simulation-based methods can help resolve success criteria issues, ambiguities in event binning, and modeling of multiple failures.
- May allow better identification of cliff edge effects and conduct of sensitivity studies.
- Improved communication by more clearly demonstrated plant impact of failures.