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

K. Coyne, C. Hunter, G. DeMoss, N. Siu
U.S. Nuclear Regulatory Commission

Y. Li , A. Mosleh
University of Maryland

Monday, June 25, 2012
PSAM11 & ESREL 2012

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Presentation Overview

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

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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 ΔCDP ≥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

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

ADS-IDAC

- 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.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

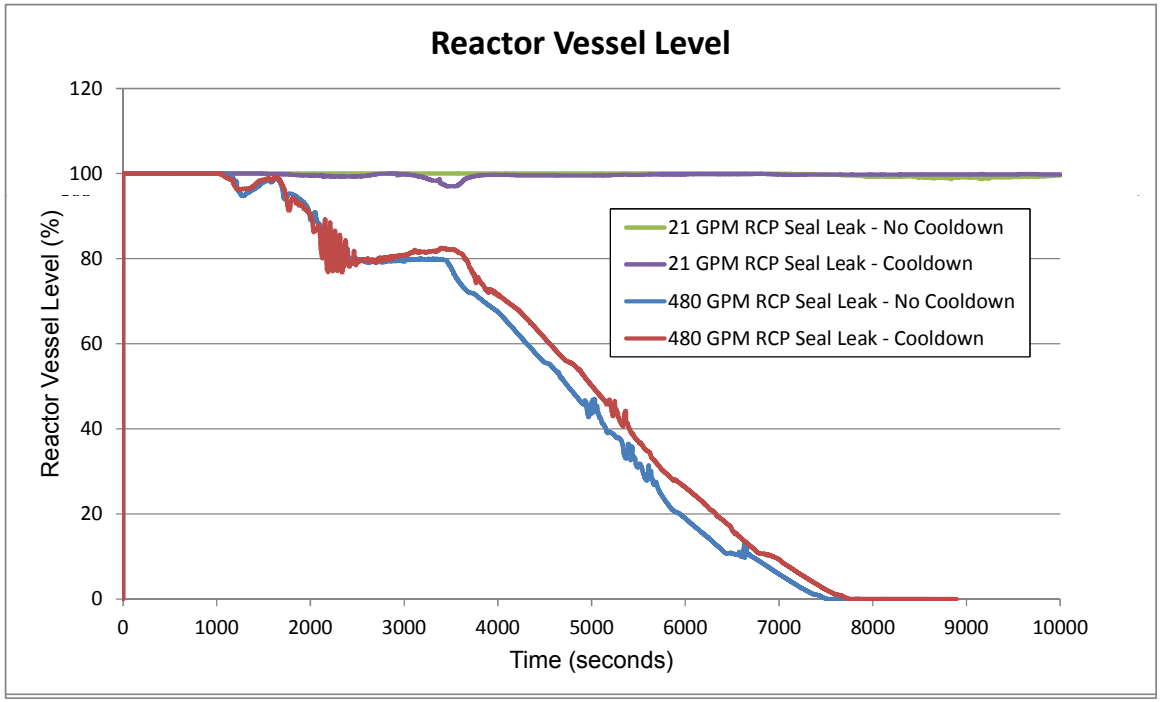
Case Study – Key Issues

- 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.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Case Study – Results & Insights

- Seal Leakage Rate
- RCS Cooldown
- Time Available



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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.