Advanced Mechanistic 3D Spatial Modeling and Analysis Methods to Accurately Represent Nuclear Facility External Event Scenarios

Project Overview

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Project Team

• Two OSU departments
  – Civil, Env. and Geod. Engineering, H. Sezen (PI)
    • J. Hur, Jr. Faculty
    • M. Kose, Visiting Professor for one year (12/2014 to 12/2015)
    • S. Uwizeramana, MS (graduated 12/2015)
    • E. Althoff, MS candidate
    • J. Fan, PhD candidate
  – Mechanical and Aerospace Engineering (Nuclear Program), T. Aldemir
    • Z. Jankovsky, PhD candidate
    • B. Cohn, PhD candidate (will receive MS degree soon)
    • A. Guler (Yigitoglu), PhD, ORNL (graduated 12/2015)
  – Consultant, R. Denning
• Structural engineering contractor – RIZZO Associates
  – F. Alemdar and N. Vaidya (co-PI)
• INL interface – C. Smith, J. Coleman
Program Rationale

The current industry methodology and tools (largely developed with EPRI support) have a number of strengths:

– Treatment of both aleatory and epistemic uncertainties.
– Well supported by training and procedures.
– Widely reviewed – Satisfies needs of ASME PRA standard and regulatory guides for PRA.
– Efficient treatment of fragilities.
– Use of common methodology among utilities simplifies regulatory review.
Limitations are identified not to be critical of the methods but to recognize areas of vulnerability as technical and regulatory issues arise.

- A stylized treatment of component fragility, which includes considerable expert judgment.
- A multiple factors approach to the combination of uncertainties using log normal distributions that is approximate but probably conservative.
- Limited ability to perform detailed uncertainty analyses because of the computational cost of detailed finite element (FE) analysis.
Potential Limitations of Existing Methods (2/2)

- Use of fixed event trees - Aspects of seismic events might be better addressed with dynamic event trees:
  - Human performance in the recovery of safety functions (e.g. implementation of FLEX equipment).
  - Effects of aftershocks.
- Limited treatment of Common Cause Failure (CCF), typically using guidelines rather than through analysis.
- Limited capability to address seismically induced fires and floods.
- Verification of results usually not possible.
Program Objectives

- The goal of the program is to provide advanced methods of seismic PRA to be used in the verification of industry methods and to support potential industry needs in the resolution of seismic issues.
- Specific areas in which the tools under development in the Light Water Reactor Sustainability Program could be of benefit SPRA include:
  - Efficient performance of uncertainty analyses, including ability to perform high fidelity FE uncertainty analyses.
  - Assessment of CCF probability in a more rigorous manner.
  - Treatment of multi-physics issues on a common platform, including seismically induced flooding.
  - Performance of DET analysis to support assessment of recovery actions.
  - Verifiability of results.
Project Framework

- Hazard characterization
- Soil-structure interaction
- Stick or FE model development
- Visualization
- CAD plant & SSCs
- Fragility database
- Identify critical SSCs

Software Tools:
- RAVEN (uncertainty)
- DINOSAUR (structural analysis)
- SAPHIRE
- MOOSE

Commercial FE, analysis software

Component failure
Major Activities

1. Input ground motion – site characterization
2. Identify SSCs for SPRA and fragility (case studies)
3. Finite element (FE) models of selected SSCs
4. FE and simplified analysis of SSCs: DINOSAUR/MOOSE, ANSYS, SAP2000
5. Development fragility parameters for SSCs
6. Failure probabilities (fragilities) of selected SSCs
7. Combined failure of SSCs with internal events

Duration: February 2014 to January 2017 (September 2017)
Seismic PRA Process/Framework

1) Hazard analysis
   • maximum acceleration
   • risk level

2) Structural models & analysis
   • calculate accelerations
   • displacements

3) Fragility analysis:
   • Accelerations and displacements
   • Failure probabilities

4) Internal events PRA, dynamic event trees
Three Case Studies

Case Study 1:

Case Study 2:

Case Study 3:
Publications (1/2)


