PRA Uncertainty Workshop
Feb. 29 – Mar. 1, 2012

Seismic Session Summary Presentation

John Lehner
Brookhaven National Laboratory

Expert presentations by

- Jim Xu
- Ravi Ravindra
- Annie Kammerer
- Greg Hardy

Sources of Seismic Uncertainty

Grouped sources of uncertainty according to the three parts of the PRA analysis:

- Hazard analysis
- Fragility analysis
- Plant response model

Sources of Uncertainty for Hazard Analysis

- Seismic source characterization
  - SHA-C
- Ground motion characterization
  - SHA-D
- Site response/amplification
  - SHA-E

Source 1: Seismic source characterization

- The source characterization is the initial input to the hazard analysis which itself is the start of the PRA analysis
- Therefore, the uncertainty in the source characterization will be propagated through the PRA to the results.

Source 1: Seismic source characterization

- Model Uncertainty Significance
  - MEDIUM
  - Some progress has been made in improving source characterization:
    - Central and Eastern United States Seismic Source Characterization for Nuclear Facilities, documented in NRC's NUREG-2115, DOE/NE-0140, and EPRI 1021097

Source 1: Seismic source characterization

- The Central and Eastern United States Seismic Source Characterization for Nuclear Facilities updates the approach to source geometry and earthquake recurrence.
- Further resolution probably not needed at this time.

Source 2: Ground Motion Characterization

- The ground motion characterization is a key input to determining the plant response to the seismic sources and therefore the plant specific hazard analysis

Source 2: Ground Motion Characterization

- Model Uncertainty Significance
  - HIGH
  - The uncertainty in the ground motion characterization drives the uncertainty of the hazard analysis. The Ground Motion Prediction Equations (GMPE) have high associated uncertainty.

Source 2: Ground Motion Characterization

- Development of Next Generation Attenuation (NGA) relationships is underway to characterize attenuation relationships for central and eastern North America. This follows completion of NGA west.
- Expect results by 2014.
- Need for further resolution should await outcome?

Source 3: Site Response

- The site response is the product of the hazard analysis that, together with the fragility analysis will determine the plant response to the earthquake

Source 3: Site Response

- Model Uncertainty Significance
  - HIGH for soil sites
  - LOW for rock sites
  - Up to date geo-technical information lacking for many plant sites
  - Site response techniques not as standardized as hoped

Source 3: Site Response

- Some resolution could be achieved with better plant specific data, avoiding overly simplified assumptions in site response techniques ?

Sources of Uncertainty for Fragility Analysis

- Soil – structure interaction (SSI)
  - SFR-C,
- Conservative assumptions of impact of structural failures
  - SFR-D
- Inadequate fragility test data
  - SFR-F
- Plant-specific loss of offsite power fragility
  - SFR-A thru F

Source 1: Soil – Structure Interaction (SSI)

- The soil-structure interaction is one of the basic inputs to the fragility analysis

Source 1:Soil – Structure Interaction (SSI)

- Model Uncertainty Significance
  - HIGH
  - Identified as a significant source of uncertainty

Source 1:Soil – Structure Interaction (SSI)

- Further resolution with better models ?

Source 2: Conservative Assumptions of Impact of Structural Failures

- Conservative assumptions of failures of structures leading to functional failure of attached equipment, for example, can produce a bias in PRA results

Source 2: Conservative Assumptions of Impact of Structural Failures

- Model Uncertainty Significance
  - MEDIUM
  - Carried out to make analysis more efficient, but conservative fragility evaluation of one SSC may mask the contribution of other SSCs

Source 2: Conservative Assumptions of Impact of Structural Failures

- Could in theory be narrowed with more detailed analysis, but at significantly more expensive PRAs?

Source 3: Inadequate Fragility Test Data

- Test data plays an important role in obtaining plant-specific fragilities

Source 3: Inadequate Fragility Test Data

- Model Uncertainty Significance
  - MEDIUM
  - Fragility tests are rarely done; a single qualification test is done and failure level has to be extrapolated

Source 3: Inadequate Fragility Test Data

- To resolve, more testing could be performed but testing is expensive

Source 4: Plant-specific Loss of Offsite Power Fragility

- The LOOP fragility is a very significant part of the plant response

Source 4: Plant-specific Loss of Offsite Power Fragility

- Model Uncertainty Significance
  - MEDIUM
  - The loss of offsite power fragility should be revisited; plant specific examination is needed, may lead to some reduction in conservatism

Source 4: Plant-specific Loss of Offsite Power Fragility

- Resolution could be achieved with better plant-specific analyses. Cost?

Sources of Uncertainty for Fragility Analysis

- The following sources of uncertainty were considered to be of LOW significance:
  - Simple lognormal model by convention
  - Different models (e.g., SRSS and Absolute Sum) for mode combinations are embedded in the fragility method
  - Critical failure modes evaluated; contributions from other failure modes are judged negligible
  - Premature screening out of SSCs
  - In some applications, the so-called Hybrid method is used wherein the HCLPF capacity is calculated and the median capacity is estimated using a generic beta C value.

Sources of Uncertainty for Plant Response Model

- Treatment of human errors under seismic conditions
  - SPR-B

Source 1: Treatment of Human Errors Under Seismic Conditions

- Putting multipliers on non-seismic failure rates to estimate seismic impact on human error is relatively crude approach

Source 1: Treatment of Human Errors Under Seismic Conditions

- Model Uncertainty Significance
  - HIGH
  - While increasing the human failure rate for many actions may not have much impact, often a few particular human actions can have a very significant impact on the PRA results

Source 1: Treatment of Human Errors Under Seismic Conditions

- Very difficult to resolve, i.e. to realistically estimate human failure rates under seismic conditions

Sources of Uncertainty for Plant Response Model

- The following sources of uncertainty were considered to be of LOW significance or of unknown significance:
- LOW significance:
  - Assumptions on initiating events and SSCs
  - Success probabilities not fully considered
  - Treatment of correlations; "one fails-all fail"
- Unknown significance (assigned MEDIUM)
  - Contribution from relay chatter effects not fully evaluated
  - Seismic Induced Fire
  - Seismic Induced Flood

Sources of Seismic Uncertainty

In very "simple" view of the uncertainties in the three parts of the PRA analysis:

- Hazard analysis HIGH
- Fragility analysis MEDIUM
- Plant response model LOW