All's Well in SPRA Land!

Outline

➢ Methodology

➢ Applications

➢ Data Sources

➢ PRA Standards in US and other countries

➢ Peer Review

➢ Resources

➢ Special Topics

SPRA Methodology

➢ Combines seismic hazard and fragilities in a plant response model

➢ Uncertainties (aleatory and epistemic) in hazard and fragilities are identified and propagated in the quantification of risk metrics such as CDF and LERF

➢ Mean CDF (LERF) and confidence bounds are generated.

➢ Many EPRI, NUREGs, and IAEA guidance documents are available.

Seismic Hazard

➢ In the 1980's, there was much confusion and controversy regarding seismic hazard

➢ The seismic hazard methodology originally developed by Dr. Allin Cornell has been improved over the years and is well accepted by the scientific community

➢ Senior Seismic Hazard Analysis Committee (SSHAC) methodology on expert elicitation and development of community distribution on hazard parameters

➢ SSHAC approach has been applied to all US nuclear power plant sites and we have seismic hazard curves now.

➢ SSHAC methodology has also been applied for the Swiss nuclear power plant sites (PEGASOS project)

Seismic Fragility

➢ Fragility methodology has seen vast improvement over the years; procedures for identification of failure modes and calculation of capacities along with uncertainties.

➢ Experience data from major earthquakes near industrial facilities and nuclear power plants

➢ Qualification test data at different plants and fragility test data (EPRI, NRC and Japan)

➢ Emphasis on detailed walkdowns to look for vulnerabilities and failure modes.

Plant Response Analysis

➢ Initiating events (LOOP, small LOCA, medium LOCA, large LOCA, and vessel rupture)

➢ Hazard levels and fragilities of SSCs

➢ Non-seismic failures, operator errors and success events

➢ Seismic risk quantification including propagation of uncertainties.

Applications

➢ Seismic PRAs have been performed for nuclear power plants in the US, Belgium, Canada, Czech Republic, France, Finland, Germany, Slovenia, Sweden, Switzerland, United Kingdom, China, Japan, South Korea and Taiwan.

➢ Seismic PRA has been used in identification of severe accident vulnerabilities, in risk informed applications and to address post Fukushima NTFF issues.

➢ Seismic PRA is required by the NRC as part of new reactor design and licensing.

Data Sources

- ➤ Hazard Analysis
  - Seismic source characterization
  - Ground motion models
  - Seismic hazard curves for sites on a regional analysis
- ➤ Fragility Analysis
  - Procedures in EPRI and NRC documents
  - Plant specific analysis supported by walkdown
- ➤ Plant Response Analysis
  - EPRI and proprietary software

PRA Standard

➤ Addendum b of ASME/ANS RA-S -2008 "Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications" was published in 2013

➤ The next edition is expected in 2019.

➤ Working Group on External Hazards has over 40 active members.

➤ The Standard provides High Level Requirements and Supporting Requirements for different elements of PRA

➤ Seismic PRA elements:
- Seismic hazard analysis
- Seismic fragility analysis
- Plant response analysis and quantification

➤ Peer review is an essential activity in the PRA; there are requirements on composition, qualifications and conduct of peer review

Seismic PSA Standards in Other Countries

- ➤ Germany: "Methoden zur Probabilistichen Sicherheitsanalyse für Kernkraftwerke" August 2005
- ➤ Finland: Radiation and Nuclear Safety Authority (STUK) "Probabilistic Safety Analysis in Safety Management of Nuclear Power Plants", Guide YVL 2.8, May 2003
- ➤ Japan: "Seismic PSA Implementation Standards" by the Atomic Energy Society of Japan, 2007
- ➤ IAEA "Attributes of Full Scope Level 1 Probabilistic Safety Assessment (PSA) for Applications in Nuclear Power Plants" IAEA-TECDOC-1804, IAEA, Vienna, 2016

Peer Review

- ➢ Peer review is an essential part of seismic PRA per the ASME Standard

- ➢ Requirements on the composition and qualification of peer reviewers are specified. Documentation of peer review observations and findings is expected to assist the utility and the NRC in risk informed decisions.

Resources

➤ Availability:
- Hazard (geologists and seismologists)
- Fragility (structural and mechanical engineers at utilities and consulting companies; younger engineers are trained in probabilistic methods)
- Plant response (PRA analysts experienced in seismic PRA)

➤ Training:
- EPRI conducts detailed training on different aspects of seismic PRA to member utilities
- NRC has a program to train its staff on SPRA and to draw from national laboratories.

Special Topics

➢ Rational treatment of seismic correlation

➢ Seismic fragility of LOOP

➢ Seismic induced fire and flooding

➢ Bayesian updating of fragilities