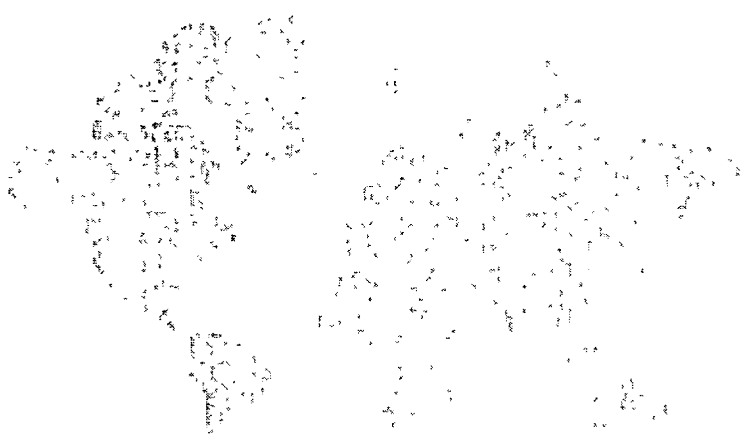
PSA METHODOLOGY AT AECL

Presented by
Hymie Shapiro
Principal Engineer PSA
PSA & EOP Supervisor
Qinshan CANDU Project



AECL EACL

Canada

PSA METHODOLOGY AT AECL

- Introduction
- PSA Scope
- Mini PSA
- Conceptual PSA
- Detailed PSA
- Generic PSA
- Conclusion

Introduction

- PSA assesses the NPP by determining the frequency and consequences of initiating events and subsequent mitigating system success and failures
- Need to analyse the plant in an integrated fashion which identifies plant vulnerabilities
- AECL applies PSA as input to design decisions on plant safety

PSA
Scope

- Level Zero- Reliability analyses of individual systems (e.g.. SDS1, SDS2, ECC, and Containment)
- Level 1- Determination of the summed severe core damage frequency inside containment
- Level 2- Determination of summed frequencies and magnitude of release at the containment boundary (usually referred to as "Source Term")
- Level 3 - PSA - Determination of frequencies of human (early and late fatalities) and environmental damage (land & air contamination)

Mini PSA

- Objective was to assess the CANDU 3 conceptual design to confirm whether PSA targets will be met during the detailed design phase. Identify design improvements early, due to the tight construction schedule
- Selected accident sequences were assessed based on previous PSA work [safety design matrices]
- High level fault trees prepared for selected CANDU systems

Conceptual PSA

- Applied to CANDU 3 and CANDU 9 to assess the conceptual designs, to confirm configuration for the detailed design phase
- About 20 internal initiating events were selected when the plant is at 100% full power and shutdown state
- Large event trees and high level (small) fault trees
- Derived summed severe core damage frequency to see if EPRI ALWR Level 1 PSA targets are met
- Reliability data:
  - hardware component data was based on OPG operating experience .
  - human reliability data was based on the simple Safety Design Matrix HRA model
- Identified design improvements and confirmed design configuration and support system interfaces

Detailed PSA

- Detailed PSAs have been or are being prepared for CANDU 6 plants under construction , specifically Wolsong 2,3, & 4 and Qinshan CANDU 1&2
- These are Level 1 + PSAs for internal events
- Small event trees and large fault trees
- Tools: CAFTA suite of codes from SAIC in the USA
- Reliability Data:
  - component data from DARA
  - human data based on diagnosis model: MCR and EOPs are not available during plant construction
- PSA targets:
  - special safety system unavailability
  - individual sequence and summed severe core damage frequency
  - frequency vs. dose limits for design basis events

Generic PSA

- Generic PSA started in April 1998 with the purpose of
  - strengthening AECL's line of PSA products and
  - identifying cost effective design and procedural enhancements
- Level 1 PSA Enhancements
  - improved human reliability modeling
  - common cause failure analysis
- External Events
  - seismic
  - fire
  - floods
- Level 2 PSA
  - severe core damage analysis with MAAP4 CANDU selected as the primary tool

Common Cause Failure Analysis

- CCFs are dependent failures which compromise the purpose of diversity & redundancies, e.g.
  - defective manufacturing process
  - component design errors
  - harsh environment (smoke, high temperature, humidity)
  - inadequate test, operating or maintenance procedures
  - human errors
  - external hazards (RFI/EMI)

- For CANDU 6 PSA, UPM approach (partial beta model is being used)
  - allows β factors to be assigned based on design assessment
  - quantitative aspects from historical data of PWRs in US & Europe

Why UPM?

- CANDU CCF data has not been collected
- extent of generic data applicability and availability for CANDU components and configurations is an issue
- UPM criteria can fulfill a design audit role, providing designers with an indication of best practices and their quantitative impact.

Example - Separation

Components in same room
Components separated by barrier
Components in adjacent rooms
Components in non-adjacent rooms
Components in separate buildings

Decreasing partial beta-factor

Generic Seismic PSA Approach

- Determination of seismic hazard at the site (calculation of frequency of earthquakes of various size and type of motion).
- Evaluation of seismic local ground motion and building motion.
- Responses of plant systems and components, spatial interactions, plant configuration (seismic walkdown).
- Fragility analysis of components and structures.
- Plant systems analysis and human reliability analysis.
- Accident sequence quantification.
- Uncertainty and sensitivity analyses.

Seismic Margin Assessment - Background

- Initially EPRI proposed Seismic PSA for ALWRs with an envelope hazard for accident sites
- NRC did not agree with proposed hazard
- EPRI proposed SMA (success path- address components which need to survive after seismic for a safe & stable shutdown)
- NRC's existing methodology for SMA was based on analysis of three events (Loss of offsite power, loss of all feedwater & small LOCA)
- NRC did not accept EPRI's SMA since it did not provide detailed insights re equipment failure, human errors, CCFs etc)
- Subsequently, NRC recommended PSA based SMA (SECY 93-87)

Acceptance of Seismic Margin Assessment

- ~ half the IPEEE submittals to NRC are Seismic PSA;
  the other half are SMA

- PSA based SMA performed for new (ALWR type) designs:
  - KNGR (0.5 g plant HCLPF for a 0.3g DBE site)
  - AP600
  - EUR

- AECB also indicated that SMA is preferred to seismic PSA

- SECY 93-87 covers PSA based SMA

Generic Flooding PSA Approach

- Identify Potential Significant Flooding Sources and Related Areas
- Estimate Flooding Frequency : Pipe/Valve, Expansion Joint, Tanks (WASH-1400, Generic Failure Data)
- Identify PSA-Credited Equipment in the Areas of Concern
- Evaluate Flood Growth and Flood Propagation : Flood Flow Rate, Floodable Volume, Flood Barrier, etc.
- Develop Flood Scenarios Considering Flood Protection Design Features and Operator Intervention
- Estimate CCDP for Each Flood Scenarios
- Estimate CDF Combining the Flood Scenario Frequency and CCDP
- Sensitivity Analysis and Insights for Risk Management

Generic Fire PSA Approach

- Identify Potential Significant Fire Areas
- Identify Ignition Sources : FHA and/or C-6 Equipment Data Base
- Estimate Fire Frequency : CANDU Fire Data Base
- Identify PSA-Credited Equipment : C-6 Equipment Data Base and Train/Channel Based Assumption for the Cables
- Evaluate Fire Growth and Propagation : COMPBRN IIIe or hand calculation
- Develop Fire Scenarios Including Fire Detection and Suppression Probability
- Estimate CCDP for Each Fire Scenarios
- Estimate CDF Combining the Fire Scenario Frequency and CCDP
- Sensitivity Analysis and Insights for Risk Management

MAAP4 CANDU for CANDU 6

- Code capabilities
  - CANDU 6 Plant
    - Single C6 containment
    - In-containment dousing tank and spray
    - PHTS (core heatup, Two figure of 8 loop)
    - Four individual Steam Generators, Pressurizer, Calandria Vessel
    - HP, MP and LP ECC
    - End-shield cooling
    - Reactor vault

MAAP4 CANDU: Preliminary Results for CANDU 6

- Station Blackout Scenario
  - Loss of Class IV and subsequent loss of all onsite standby Electric Power Supplies
  - Emergency Electric Power Supply not credited
  - Reactor shut down
  - ECCs (HPI, MPI and LPI) unavailable
  - Containment dousing spray and LACs unavailable
  - Main and Auxiliary Feedwater systems unavailable
  - Emergency Water Supply system unavailable
  - Moderator and Endshield Cooling systems unavailable
  - No credit for operator interventions

Summary of SBO data (preliminary, hours)

- First opening of MSSV 0.13 h
- SG secondary side dry 2.2 h
- LRV first opening 2.4 h
- At least one channel dry 4.2 h
- CV rupture disk 1 opens 5.5 h
- PT and CT rupture 8.6 h
- Containment failure by press. increase 39.2 h
- CV failure 61 h
- RV floor by corium/concrete interaction 129.4 h

Conclusion

- Depending on the objectives and state of plant design, PSA can been used as a cost effective design tool to:
  - identify design improvements
  - confirm design configuration and support system interfaces
- PSA can be used as support for operation
  - Technical specification chapter of safety reports (OP& P and impairment manuals)
  - Input to emergency operation procedures
  - Maintenance strategy

AECL
Atomic Energy
of Canada Limited

EACL
Énergie atomique
du Canada limitée