Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

Canada

Human Reliability Analysis Methodologies used in the Canadian Probabilistic Safety Assessment for external events

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Outline

- Background
- PSA Regulatory Requirements
- HRA for Internal Events
- HRA for External Events
- HRA HRA Challenges
- Conclusions

Background: NPPs in Canada

- Two types of operating CANDU NPPs in Canada:
  - Single-unit NPP
    - Point Lepreau Station
    - Gentilly 2 (in safe storage)
  - Multi-unit NPPs:
    - Four-unit Bruce A, Bruce B, and Darlington stations
    - Six-unit Pickering Station ("A" and "B" sides)

Background (Cont.)

Operable status

In service

Safe storage state

In refurbishment

Bruce

A1: In service 1977/2012 MWe 750

A2: In service 1977/2012 MWe 750

A3: In service 1978/2003 MWe 750

A4: In service 1979/2003 MWe 750

B5: In service 1985 MWe 882

B6: In service 1984 MWe 882

B7: In service 1986 MWe 882

B8: In service 1987 MWe 882

Darlington

1: In service 1992 MWe 881

2: In refurbishment Oct 2016 MWe 881

3: In service 1993 MWe 881

4: In service 1993 MWe 881

Pickering

A1: In service 1971/2005 MWe 515

A2: In service 1971, Currently in Safe storage state

A3: In service1972, Currently in Safe storage state

A4: In service 1971/2003 MWe 515

B5: In service 1983 Mwe 516

B6: In service 1984 Mwe 516

B7: In service 1985 Mwe 516

B8: In service 1986 Mwe 516

Point Lepreau NB

In service 1983/2012 MWe 705

Gentilly-2 QC

In Safe Shutdown since Dec. 28, 2012

Regulatory Requirements on PSA

Scope and Depth of Regulatory Review

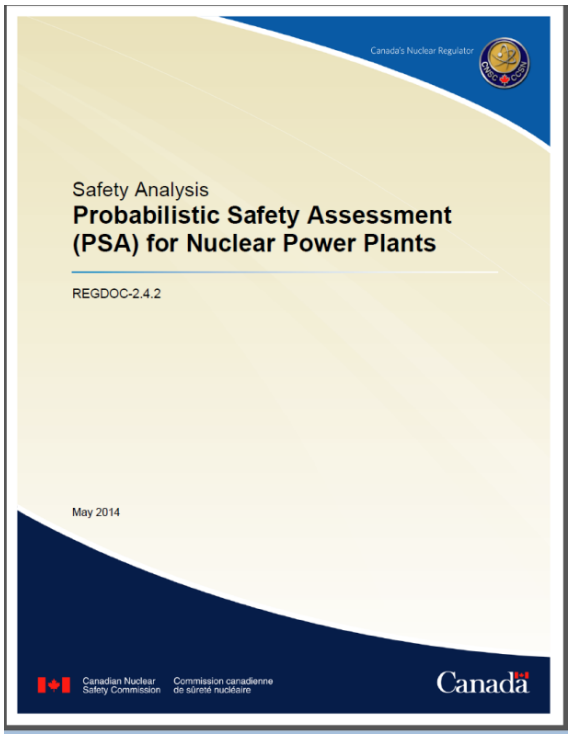
Licensees are required to:

- Conduct Level 1 and Level 2 PSA with a formal QA process
- Consider both internal and external events
- Update PSA every 5 years
- Perform uncertainty, sensitivity, and Importance analyses
- **Seek CNSC acceptance of the PSA Methodology,** including HRA methodology

Regulatory Review Process:

The review of PSA reports is performed by CNSC (CNSC-PSA review procedure)

1. Stage 1 Review: Qualitative review
2. Stage 2 Review: Quantitative review, including HRA



General Status of PSA in Canada

PSA Submissions

Licensees complete

- **Level 1 and Level 2 PSA for:**
  - Internal events
  - Internal fires
  - Internal floods
  - Seismic events
  - High wind (NB Power did high hazard assessment and wind fragility analysis)

✓ **20 PSA Elements**

Hazard Type	Hazard Group	Level 1		Level 2	
		At power	Shutdown state	At power	Shutdown state
Internal Hazards	Internal events	☑	☑	☑	☑
	Internal Fires	☑	☑	☑	☑
	Internal Floods	☑	☑	☑	☑
External Hazards	Seismic Events	☑	☑	☑	☑
	High Winds	☑	☑	☑	☑

✓ **Screening analysis reports for other internal and external hazards**

History of Human Reliability Approaches

Late 70s: HRA used in Safety Design Matrices (SMD)

- Prepared for Bruce B, Pickering B
- Focus on post-accident human error.

Time (min)	T < 15	15 < T < 30	T > 60
HEP	1	0.01	0.001

1987: HRA used in Darlington Probabilistic Safety Evaluation (DPSE)

- A detailed human interaction (HI) taxonomy was developed
- Both pre- and post- initiating event human error probabilities are considered.

In 1995, HRA in PSA studies of the National Research Universal (NRU) reactor upgrades (AECL).

- Considerations of PSFs and accounting for dependencies between human error events
- The values of basic HEPs were determined based on SHARP , HEART and THERP

In 2001, AECL developed the HRA methodology for the Level 1 PSA based on the Accident Sequence Evaluation Program (ASEP)

Human Reliability Approaches
(Level 1 Internal Events)

- Two different approaches are used for Level 1 internal events PSA:

  1st approach: Accident Sequence Evaluation Program (ASEP) is used.

  2nd approach : licensee-specific developed HRA method:
  - Simple interactions (pre-initiating events);
  - Complex interactions (which may be either pre or post-initiating events).

- In both approaches, dominant human actions are then re-quantified using Technique for Human Error Rate Prediction (THERP; NUREG-1278).

Quantification of Complex HIs

For the 2nd approach, the quantification process consists of determining the nature of a task based on the three characteristics:

- The task type: straightforward and/or familiar, average complexity and familiarity, very complex or unfamiliar.
- The quality of indication: This may be either unambiguous indication, requires interpretation, unclear, or non-existent (four possibilities).
- The time available: This may be either unrestricted, greater than required, about equal to required, or less than required

- No credit is given for operator action if the time less than required or there is no indication.
- Multiplying factors are used for assigning the HEPs .

HRA for Internal and External Hazards

- For seismic and Fire PSAs, HRA from the internal events PSA is used as the starting point. And HEPs quantification consists of using multipliers.

- For flood and high wind PSAs, same HRA methodology for internal events is used, taking into consideration the specific context of the hazards (PSFs).

- There are differences in the multiplication factors used and more consistency is desirable.

HRA for seismic events

Seismic PSA uses the HRA from the internal events PSA as the starting point for the seismic HRA input.

HRA process for Human error probabilities (HEPs) in the seismic model includes the following steps:

- Identification of Human failure events (HFEs): (existing and new HFEs)
- Characterization of the time available to perform each identified post-initiator action
- Quantification of the post-initiator HEPs
- Modeling

HRA for Seismic PSA (cont.)

- approach used for the seismic PSA considered three primary Factors:
  - Location of Action
  - Time Available
  - Seismic Hazard Intensity: Licensees approaches consist of splitting the seismic events into G-levels.
- Multiplication factors are assigned accordingly.
  - Licensees use different multiplication factors (HEP Multipliers). For example if G-level higher than DBE, for some licensees, no credit is given to the Operator action; But for others, operator action could be credited with a high multiplier (= 1000).

HEP multipliers in Seismic PSA

Approach 1:

Seismic Intensity	HI Location	Time available
• 0 to MCRDE • MCRDE to DBE • DBE to XDBE • > XDBE	HI in the Control Room (MCR/SCA)	15 to 30 minutes
• 0 to MCRDE • MCRDE to DBE • > DBE	Operator Actions in the field	30 to 60 minutes
		> 60 min

➢The multiplier varies from 1 to 10 depending on the severity of the earthquake, time available and the location of the action.

HEP multipliers in Seismic PSA (cont.)

Approach 2:

Seismic Intensity	HI Location	Time available
Low	HI in MCR/SCR	15 to 30 minutes
Moderate	HI Outside MCR (Seismically Qualified area)	30 to 60 minutes
High	HI Outside MCR (Non-Seismically Qualified area)	> 60 min

➢The multiplier varies from 1 to 1000 depending on the severity of the earthquake, time available and the location of the action.

HRA for Fire PSA

For Fire PSAs, HRA from the internal events PSA is used as the starting point. Different assumptions are used by licensees:

- **Approach 1:** Application of multipliers (HEP from internal events) based on the location of the HIs. The multiplier varies from 1 to 5.
  - For example:
    - If HI in the field, a factor of 5 is used
    - If HI in MCR, a factor of 3 is used
    - HI in area affected by Fire HEP = 1

- **Approach 2:** An alternate approach based on NUREG/CR-6850 was developed.
  - Application of multipliers based on the timing and the location of the HIs. the HEP from the internal PSA may be retained, the HEP value may be multiplied by a factor varying from 2 to 30, or no credit for the operator action.

Other HRA Approaches

HRA for Emergency Mitigation Equipment (EME) Credits

After the Fukushima accident and the installation of EME, OPG and Bruce Power developed a separate methodology for crediting EME in PSA.

- "*Simplified Human Reliability Analysis Process for Emergency Mitigation Equipment (EME) Deployment*". (presented in PSAM-12)

Approach takes into account:

- EME transportation
- EME deployment
- EME connections

Severe-Accident Management Guidelines (SAMGs) Credits

OPG is developing a new methodology for crediting SAMGs in PSA

HRA Challenges

- The existing HRA methods were developed primarily for internal events PSA and often contain assumptions that may or may not be applicable to new conditions created by external hazards.
  - New PSFs may need to be included in HRAs to account for: the different stress levels, habitability issues, the degree of operator training, potential psychological impacts on operators and decision makers; the effects of long scenario duration (including fatigue, stress, and cumulative dose); etc...
  - Need for consistency in the application of HEP multipliers for external events PSA

Conclusions

- CNSC has regulatory requirements for the conduct of Level 1 and Level 2 PSA for internal and external events for both at power and shutdown states.
- Canadian licensees use either published HRA methodologies or licensees' specific methodologies.
- Re-quantification of dominant human interaction is generally done using THERP.
- Canadian licensees developed a new methodology for crediting EMEs.
- Multipliers are used for the quantification of HEPs for external events. More consistency in the application of these multipliers is desirable.
- New performance shaping factors (PSFs) may need to be included in HRAs to account for the new context of external events.

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