Canadian Regulatory Approach for Safe Long-Term Operation of Nuclear Power Plants

Technical and Regulatory Issues Facing Nuclear Power Plants: *Leveraging Global Experience*

June 1– 2, 2016

Chicago, IL

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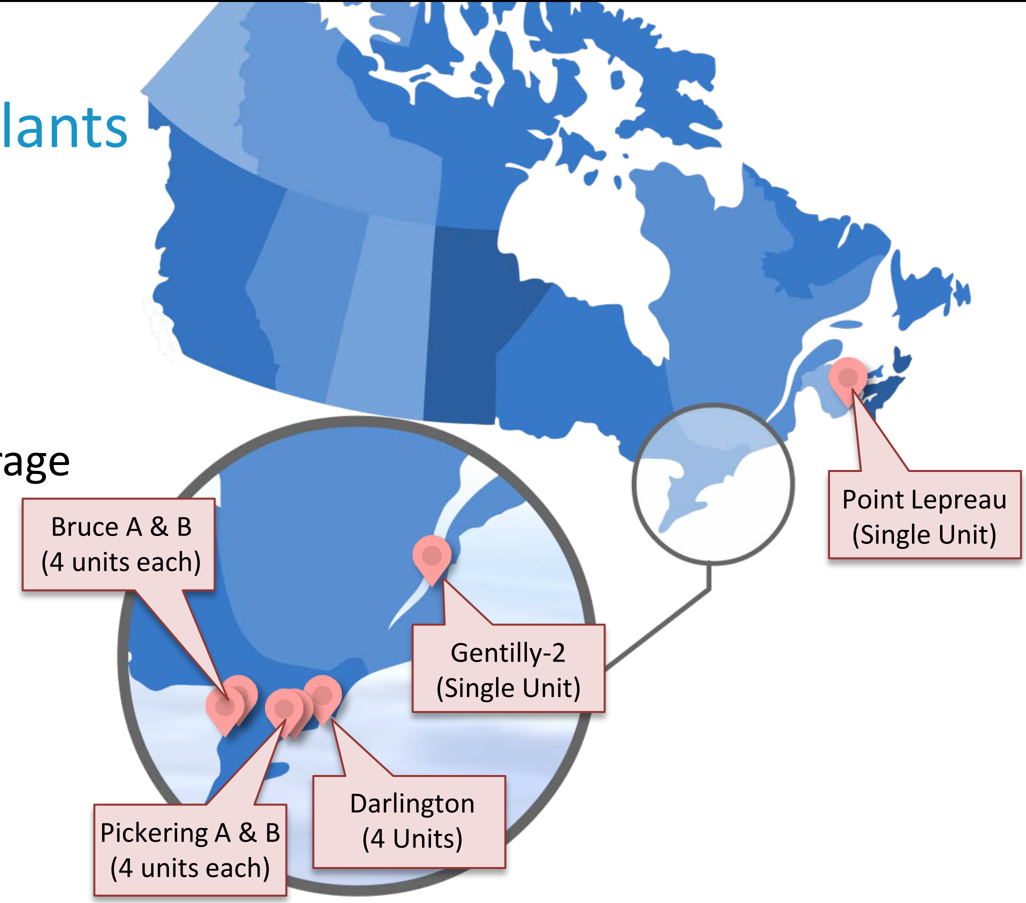
PROFILE OF CANADIAN NUCLEAR POWER PLANTS

Canada’s Nuclear Power Plants

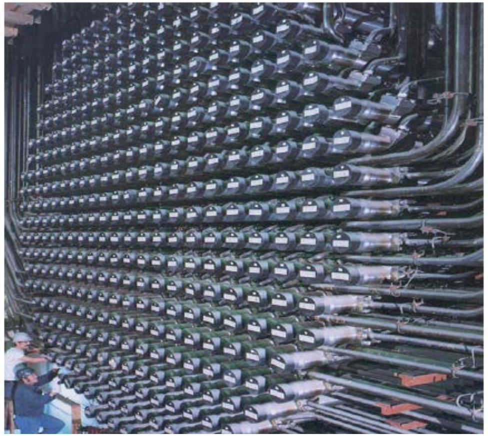
- Six nuclear power plants have operating licences
- 19 reactor units are operational
- Pickering Units 2 and 3 in safe storage
- Gentilly-2 shut down in 2012, transitioning to safe storage

Ontario’s electricity depends on nuclear power

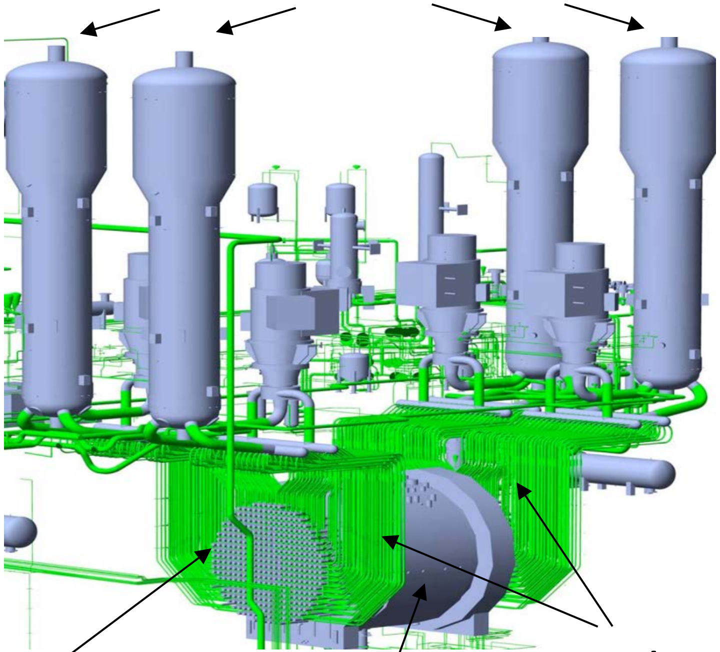


CANDU Reactor

- Pressure tube type pressurized heavy water reactor (PHWR) with calandria vessel
- Major components of primary heat transport system (PHTS):
  - Fuel channels (380 - 480 FCs*)
  - Feeders pipes (760 - 960 feeders*)
  - Steam generators (4 – 12 SGs*)



* Number of component items differs at each plant



Status of Canada's Nuclear Power Plants

- In service within design life
- Refurbished and returned to service
- Safe storage state
- Transitioning to safe storage

Bruce A and B

A1	A2	A3	A4
In service 1977/2012	In service 1977/2012	In service 1978/2003	In service 1979/2003
904 MWe	904 MWe	904 MWe	904 MWe
B5	**B6**	**B7**	**B8**
In service 1985	In service 1984	In service 1986	In service 1987
915 MWe	915 MWe	915 MWe	915 MWe

Darlington

1	2
In service 1992	In service 1990
935 MWe	935 MWe
3	**4**
In service 1993	In service 1993
935 MWe	935 MWe

Pickering

A1	A2	A3	A4
In service 1971/2005	In service 1971	In service 1972	In service 1971/2003
542 MWe	Safe storage state	Safe storage state	542 MWe
B5	**B6**	**B7**	**B8**
In service 1983	In service 1984	In service 1985	In service 1986
540 MWe	540 MWe	540 MWe	540 MWe

Gentilly-2

In service 1983

Transitioning to safe storage since Dec 2012

Point Lepreau

In service 1983/2012

705 MWe

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REGULATORY APPROACH TO LONG-TERM OPERATION

Evolution of Approach to Long-Term Operation

- Decision to refurbish is an **economic one**, made by the operator based on business needs such as
  - strategy, cost, plant condition, etc.
- Current approach to long-term operation for nuclear power plants in Canada is based on application of the periodic safety review (PSR)
  - 2000 to 2006 : IAEA documents used to guide the reviews
  - 2008 to 2015 : regulatory document RD-360, *Life Extension of Nuclear Power Plants*, was used
  - 2015 to present: CNSC REGDOC-2.3.3, *Periodic Safety Reviews,* is being used

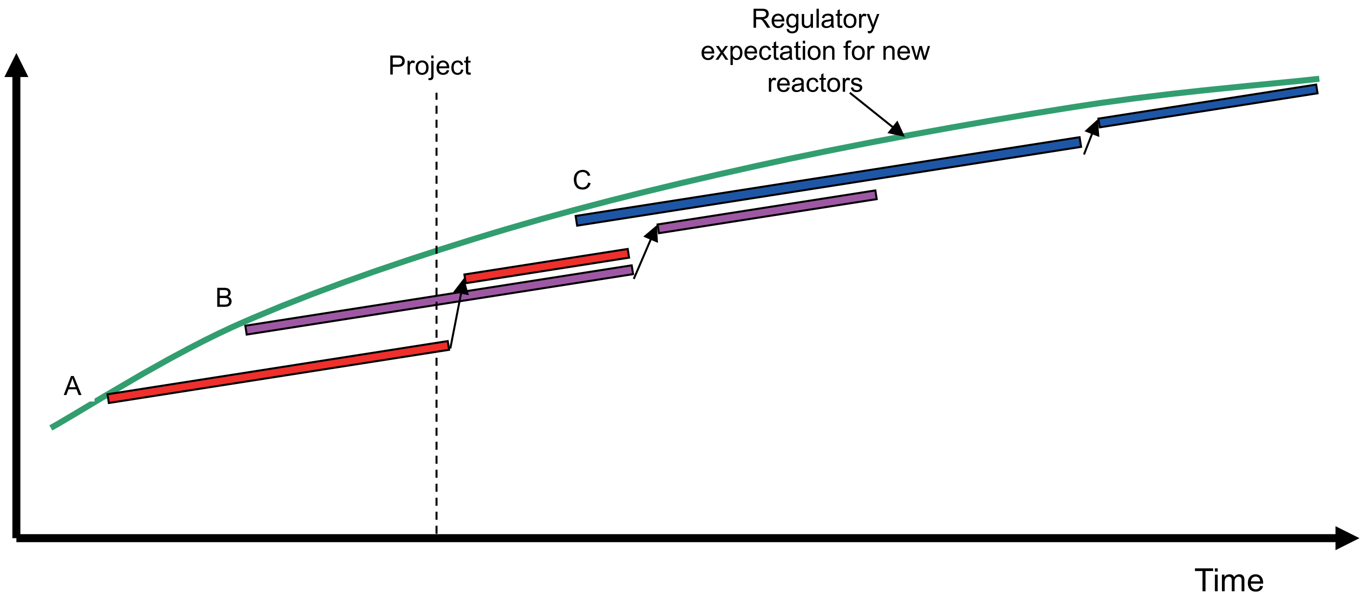
General Considerations

- REGDOC-2.3.3 requires the following to be carried out
  - periodic safety review (PSR) to establish the scope of work required for long term operation of a nuclear power plant, and
  - review against modern standards, best practices, operating experience, research findings to re-baseline the safety case
- Based on the results of the PSR, licensees establish
  - an integrated implementation plan (IIP) for the necessary plant refurbishment, safety upgrades and other compensatory measures, and
  - any gaps with modern standards must be justified and agreed to by regulator

Process Overview: Periodic Safety Review

- The periodic safety review (PSR) is a comprehensive self-assessment carried out by the licensee, guided by:
  - CNSC REGDOC-2.3.3, *Periodic Safety Reviews*
  - IAEA Safety Guide, SSG-25, *Periodic Safety Review (PSR) of Nuclear Power Plants*, 2013
- The PSR enables determination of **reasonable and practical modifications** that should be made to
  - enhance the facility's safety to a level approaching that of modern plants
  - support long-term operation

Nuclear Risk Reduction (3/3)



Process Overview: Integrated Implementation Plan

- Process involves replacement, maintenance, and/or modifications to major systems, structures and component
  - steam generators
  - fuel channels/feeders
- Licensees address modern high-level safety goals to identify safety upgrades
  - emergency filtered containment venting system
  - makeup capability to shield tank (or calandria vault) to support in-vessel retention
- Licensees may proceed with the activities supporting long term operation upon acceptance of the plan by CNSC staff
  - licence Is amended to include appropriate licence conditions for the return-to-service phase of the project

Process Overview: Return to Service

- Return to service is based on the licensee's ability to demonstrate that new and existing plant systems, structures and components conform to
  - physical, functional, performance, safety, and control requirements
- The process of returning to service includes progressing to regulatory **hold points**
  - typically aligned with facility commissioning activities, starting from fuel loading

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LONG-TERM OPERATION: CURRENT CHALLENGES

Nuclear Risk Reduction (1/3)

- Fitness for service of aging components
  - reactor units approaching assumed design life of 210,000 equivalent full power hours (EFPH)
  - verification of safe operation up to 247,000 EFPH
- Refurbishment projects
  - assessments of PSR and IIP
  - project execution
- Fukushima action items
  - licensees continuing to implement Fukushima actions through station-specific action items
- Regulatory effectiveness and transparency
- Public awareness and acceptance

Nuclear Risk Reduction: Strengthening Defence in Depth (2/3)

- Strengthened accident prevention to reduce risk to as low as reasonably practicable:
  - Inherent safety features
  - Well-balanced facility design to eliminate potential vulnerabilities
- Increased focus on accident prevention and mitigation, and emergency response to protect the public :
  - criteria for plant self-sufficiency to maintain containment integrity
  - onsite severe accident management to prevent large radiation release and avoid offsite contamination
  - integrated onsite and offsite response capability tested and regularly exercised
- Continuous safety improvements
  - operating experience (Fukushima)
  - R&D (new findings)

Regulatory Effectiveness and Transparency

- Publication of REGDOC-2.3.3, *Periodic Safety Reviews*
  - Describes the regulatory requirements and guidance for PSR implementation on a **periodic basis**
  - Move to a 10-year operating licence
  - Can be used to address long term operation beyond assumed design life
- Publication of REGDOC-2.3.1, *Conduct of Licensed Activities: Construction and Commissioning Programs*
- Development of REGDOC-1.1.3, *Licence Application Guide* (LAG) for operation
  - provides further clarity on the licence renewal requirements
  - provides mechanism for PSR reviews and IIP to be credited in licence application

Public Awareness and Acceptance

- Public awareness and understanding of the scientific, technical, economic and legal aspects of nuclear activities:
  - clarify the unknown to change public perception
  - reveal the truth instead of creating it
  - articulate clearly why nuclear energy is safe
  - emphasize actual versus probable
- Public acceptance depends on risk tolerance:
  - explain how safe is safe enough
  - effectively communicate the risk to the public to eliminate risk bias
  - communicate within a broad range of possibilities
  - compare the risk of a nuclear accident to societal risks

ADDITIONAL INFORMATION

Defence-in-Depth Framework for Nuclear Power Plants

(From: *Implementation of Defence in Depth at Nuclear Power Plants*, NEA 2016)

Level	Implementation
1. To prevent deviations from normal operation, and to prevent failures of structures, systems and components (SSCs) important to safety	• Conservative design • High quality construction (e.g., appropriate design codes and materials, design procedures, equipment qualification, control of component fabrication and plant construction, operational experience) • A suitable site was chosen for the plant with consideration of all external hazards (e.g. earthquakes, aircraft crashes, blast waves, fire, flooding) in the design • Qualification of personnel and training to increase competence. • Strong safety culture • Operation and maintenance of structures, systems and components in accordance with the safety case
2. To detect and intercept deviations from normal operation, to prevent AOOs from escalating to accident conditions and to return the plant to a state of normal operation	• Inherent and engineered design features to minimize or exclude uncontrolled transients to the extent possible • Monitoring systems to identify deviations from normal operation. • Operator training to respond to reactor transients
3. To minimize the consequences of accidents, and prevent escalation to beyond-design-basis accidents	• Inherent safety features • Fail-safe design • Engineered design features, and procedures that minimize consequences of DBAs • Redundancy, diversity, segregation, physical separation, safety system train/channel independence, single-point failure protection • Instrumentation suitable for accident conditions • Operator training for postulated accident response

Defence-in-Depth Framework for Nuclear Power Plants (2)

(From: *Implementation of Defence in Depth at Nuclear Power Plants*, NEA 2016)

Level	Implementation
4. To ensure that radioactive releases caused by severe accidents OR Design Extension Conditions are kept as low as practicable	• Equipment and procedures to manage accidents and mitigate their consequences as far as practicable • Robust containment design • Complementary design features to prevent accident progression and to mitigate the consequences of design extension conditions • Severe accident management procedures
5. To mitigate the radiological consequences of potential releases of radioactive materials that may result from accident conditions	• Emergency support facilities • Onsite and offsite emergency response plans • Plant staff training on emergency preparedness and response

Post-Fukushima Enhancements to Defence in Depth: NPP Example (1)

- **Level 3: Protecting facilities including spent fuel pools**
  - flood protection
  - makeup water capability and instrumentation

- **Level 4: Preventing and mitigating severe accidents**
  - enhanced backup power for equipment, telecommunications, and emergency facilities
  - upgraded instrumentation
  - protecting fuel
    - makeup water capability to steam generator and primary heat transport emergency core cooling and dousing spray systems
  - preventing severe core damage
    - makeup water capability to moderator system and calandria vessel/vault
    - enhanced pressure relief for calandria vessel/vault

Post-Fukushima Enhancements to Defence in Depth: NPP Example (2)

- **Level 4: Preventing and mitigating severe accidents (cont'd)**
  - protecting containment
    - passive hydrogen recombiners
    - containment cooling and filtered venting
    - severe accident management guidelines validation/exercise

- **Level 5: Protecting the public**
  - automated real-time boundary radiation monitoring
  - source term estimation capability
  - integrated emergency plans and full-scale emergency exercises
  - study of consequences of hypothetical severe nuclear accident
  - pre-distribution of potassium iodide pills

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