Canadian Experience in Application of Graded Approach for Safety Assessment of the Research Reactors

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Research reactors are typically used for basic and applied research, education and training, production of isotopes, material testing, neutron activation analysis and other purposes. Most research reactors have a small potential for hazard to the public compared with power reactors. Safety assessment for the research reactors needs to be undertaken to evaluate compliance with safety requirements and to determine the measures to ensure reactor safety. Considering the different types of research reactors and their associated utilization, safety assessment should be commensurate with the potential hazard, ensuring that the design and operation of each reactor lead to adequate safety and defence in depth.

The scope of presentation will cover the following topics:

— Canadian regulatory framework for licensing research reactors;
— Graded approach applied to safety assessment of the research reactors;
— Use of graded approach to safety assessment of SLOWPOKE and NRU reactors.

Canadian Nuclear Safety Commission (CNSC) has developed a regulatory framework for licensing small reactor facilities (including research reactors) that sets out requirements for the safety analysis and reactor design. CNSC staff considers each application individually in determining how much rigour and stringency are required for the safety assessment. All important factors affecting the overall reactor safety, such as safety system design, inherent safety features, the amount of fissile and fissionable materials, and the source terms are considered. The graded approach introduced in [1, 2, 3] allows safety requirements to be implemented in such way that the level of safety assessment is proportional to the potential hazards posed by the research reactor. Licensing requirements vary with the type of facility and they may be applied in a graded fashion based on overall risk.

Graded approach can be applied to all components of safety assessment including radiation risk, safety functions, defence in depth, engineering aspects, site characteristics and safety analysis. Examples of application of this approach to safety assessment of the Canadian research reactors, Slowpoke and NRU, are presented. The SLOWPOKE reactor (20 kW) has inherent reactivity control by design, since any increase in core temperature has a negative reactivity effect causing a passive reduction of reactor power to limit any temperature excursion. The NRU reactor (135 MW) operates at low pressure and low temperature (except for the experimental loops) and it is used for material testing and isotope production.

For SLOWPOKE reactors, less detailed assessment of radiation risk is needed in comparison to the NRU due to a smaller amount of fission product inventory in the core.

Full assessment of defence in depth is required for the high power, complex NRU reactor. However, assessment of means to mitigate severe accidents may not be needed for SLOWPOKE reactors due to their inherent reactivity characteristics.

A design of any reactor facility must provide the fundamental safety functions during and following postulated accident events. The extent and rigour for demonstrating that such safety functions are fulfilled can be graded and vary depending on the reactor design. In general, basic safety function related to control reactivity cannot be graded. However, the grading can be applied to SLOWPOKE reactors since they exhibit inherent self-limiting power levels, which physically limit the amount of positive reactivity that can be inserted in the core. Assessments of safety functions relevant to the reactor core cooling and confinement could be less extensive for the SLOWPOKE reactors since their cooling systems are less complex than those of NRU. Very small source terms of the SLOWPOKE reactors do not require a confinement system to be as stringent as those used in large research reactors. If the research reactor is designed without a confinement system (e.g., NRU), it must be justified to show that there is no potential release of radioactive materials out of the facility for any accident conditions.

Assessment of site characteristics for new reactors can be gradable. Main factors to be taken into account are the type of research reactor to be operated and activity to be conducted.

Grading can be also applied to the scope of the analysis, identification of the postulated initiating events (PIE) to be analyzed, complexity of safety analysis, analysis documentation and review and updates. Breadth and depth of safety analysis needs to be more comprehensive for NRU than for SLOWPOKE. For the latter, fewer PIEs would be applicable due to passive nature of the reactivity feedback during temperature excursions. A simplified safety analysis is acceptable for SLOWPOKE. However, a more comprehensive analysis is required for NRU to account for the effects of interfacing systems and loops (resulting in significant number of events to be analyzed). Review and updates of safety analysis are less frequent for the SLOWPOKE than for the NRU reactor.

References

[1] Canadian Nuclear Safety Commission, Regulatory Document RD-308, “Deterministic Safety Analysis for Small Reactor Facilities”, Ottawa, 2011.
[2] Canadian Nuclear Safety Commission, Regulatory Document RD-367, “Design of Small Reactor Facilities”, Ottawa, 2011.
[3] International Atomic Energy Agency, “The Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors”, IAEA Safety Standards DS351 (Draft), 2011.