Consideration of Strategies for Advancing i-SMR's Canadian VDR Process

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1. Introduction

The Vendor Design Review (VDR) is a crucial preliminary step in securing regulatory approval for new reactor designs in Canada. KHNP's i-SMR (innovative small modular reactor aims to achieve VDR approval to enhance global market competitiveness, ensure design safety, and facilitate its entry into the Canadian nuclear sector. The Canadian Nuclear Safety Commission (CNSC) plays a key role in this process by evaluating compliance with safety and operational standards [1].

While several SMR developers, such as NuScale Power and Terrestrial Energy, have undergone or are undergoing the VDR process, KHNP's i-SMR has unique design features that differentiate it from other SMRs.

This study provides an overview of the VDR process, analyzes key regulatory documents [2], and presents strategies for effective preparation and implementation [3].

2. Overview of the Canadian VDR and Related Regulatory Requirements

2.1 Overview of the VDR Process

The VDR is a three-phase evaluation conducted by CNSC to assess reactor design compliance with Canadian nuclear regulatory expectations before formal licensing applications [2]. The primary goal is to ensure the safety and maturity of the design.

- Phase 1: Assessment of the fundamental design adequacy based on CNSC's regulatory framework [2].
- Phase 2: Detailed technical review, including safety analyses and engineering evaluations [1].
- Phase 3: Final resolution of outstanding issues before submission of a formal licensing application [2].

A thorough understanding of each phase is critical for successful navigation of the VDR process [2]. Compared to large-scale reactors, SMRs face additional regulatory challenges, including demonstrating passive safety features, long-term fuel cycle sustainability, and site flexibility. These factors must be carefully addressed throughout the VDR process.

2.2 Key Regulatory Documents

The Canadian nuclear regulatory framework consists of multiple CNSC documents that govern reactor design, licensing, and operational safety [1-7]. Table 1 summarizes the key regulatory documents relevant to i-SMR's VDR process.

Table 1. Key Regulatory Documents for the Canadian VDR Process of i-SMR

Document No.	Publication Date	Key Content
REGDOC-1.1.1 [4]	2022.07	Establishes site evaluation criteria for new nuclear facilities, including seismic, environmental, hydrological, and meteorological considerations to assess site suitability and potential hazards.
REGDOC-2.3.2 [5]	2017.03	Defines requirements for accident management programs, covering preventive, mitigative, and emergency response strategies to enhance plant resilience against design-basis and beyond-design-basis events.
REGDOC-2.4.1 [6]	2019.12	Provides deterministic safety analysis (DSA) methodologies to evaluate plant response to operational states, anticipated transients, and accident scenarios, ensuring regulatory compliance with safety margins.
REGDOC-2.4.2 [7]	2020.05	Establishes probabilistic safety assessment (PSA) guidelines, including Level 1 (core damage frequency) and Level 2 (containment failure probability) risk evaluations to support regulatory decision-making.
REGDOC-2.5.2 [1]	2019.07	Specifies comprehensive reactor design and safety requirements, including nuclear fuel integrity, cooling system performance, severe accident mitigation, containment structure robustness, and radiation protection measures.
REGDOC-3.5.4 [2]	2021.09	Outlines the full Vendor Design Review (VDR) process, including detailed criteria for Phase 1 (conceptual design review), Phase 2 (detailed technical assessment), and Phase 3 (resolution of outstanding issues before licensing).
RD-367 [3]	2011.06	Defines specific safety and design requirements for small reactors, differentiating them from large-scale nuclear power plants while maintaining regulatory consistency in safety principles.

2.3 CSA Standards for VDR Compliance

Alongside CNSC regulations, Canadian Standards Association (CSA) standards provide essential compliance guidelines for structural, seismic, and operational safety in nuclear power plants [8-12]. Table 2 highlights key CSA documents relevant to the i-SMR VDR process.

Table 2. Key CSA Documents Related to VDR

Document No.	Publication Date	Key Content
CSA N285.0-23 [8]	2023.01	Specifies design, material selection, inspection, and maintenance requirements for pressure-retaining systems and components, ensuring the structural integrity of reactor coolant systems in CANDU reactors.
CSA N287.1-14 [9]	2014	Establishes criteria for the design, construction, and testing of concrete containment structures, including requirements for prestressed and reinforced concrete to withstand internal and external hazards.
CSA N293-22 [10]	2022.07	Provides fire protection guidelines for nuclear power plants, addressing fire prevention, detection, suppression, and response planning to minimize fire-induced risks to safety-related systems.
CSA N286-19 [11]	2019.08	Defines management system requirements for nuclear power plants, including quality assurance in design, procurement, construction, commissioning, operation, and decommissioning processes.
CSA N289.1-17 [12]	2017.03	Establishes requirements for seismic design and qualification of structures, systems, and components (SSCs) to ensure plant resilience against site-specific earthquake events.

3. i-SMR VDR Preparation Strategy

To successfully complete the VDR process, the i-SMR team must meticulously prepare by ensuring documentation, design reviews, stakeholder engagement, and benchmarking past VDR cases [1,2].

3.1 Documentation and Technical Report Preparation

To meet CNSC's regulatory expectations, the i-SMR design must be supported by:

- Safety Analysis Report (SAR).
- Radiation Protection Plans.
- Accident Response Strategies.

3.2 Design Review and Technical Enhancements

i-SMR's design should undergo rigorous assessment against REGDOC-2.5.2 and CSA standards, focusing on:

- Passive safety systems.
- Severe accident mitigation strategies.
- Cooling system reliability.
- Containment robustness.

3.3 Collaboration with CNSC and Stakeholders

Early engagement with CNSC and Canadian nuclear stakeholders is essential to ensure that i-SMR's deterministic safety analysis (DSA) and probabilistic safety assessment (PSA) methodologies align with regulatory expectations. Establishing a structured dialogue with CNSC during the Vendor Design Review (VDR) process will provide technical insights into accident scenario modeling, safety margins, and defense-in-depth strategies.

Additionally, collaboration with Canadian nuclear industry partners will support the validation of passive safety system performance and enhance the credibility of best-estimate and uncertainty analysis (BEAU) methodologies applied to i-SMR. By incorporating stakeholder feedback into safety assessments, i-SMR can proactively address potential regulatory challenges and optimize its compliance strategy for licensing approval.

3.4 Benchmarking and Case Studies

To enhance the efficiency of the i-SMR's VDR process, lessons from previous SMR vendors' experiences should be integrated.

- NuScale Power: The first SMR to receive U.S. NRC design approval, demonstrating compliance with modular construction and passive safety systems.
- Terrestrial Energy: A Canadian SMR developer currently in the VDR process, focusing on molten salt reactor (MSR) technology.

By analyzing past VDR cases, KHNP can identify regulatory concerns that frequently arise and develop proactive strategies to mitigate them.

4. Challenges and Considerations

The i-SMR team must address several challenges, including:

- Adapting the design to Canadian regulatory expectations.
- Bridging gaps between Korean and Canadian nuclear safety frameworks.
- Managing financial and time constraints associated with VDR.
- Ensuring compliance with evolving regulatory requirements, as CNSC frequently updates REGDOCs based on technological advancements and global best practices.

Developing mitigation strategies to address these challenges is essential for ensuring a smooth regulatory approval process. One of the key challenges is aligning i-SMR's safety analysis methodology with CNSC's

expectations, particularly in areas such as probabilistic safety assessment (PSA) and deterministic safety analysis (DSA). Early engagement with CNSC and proactive alignment with updated REGDOCs will be critical.

5. Conclusions

This study analyzed the technical requirements and strategies for i-SMR's successful VDR process in Canada. Key takeaways include:

- Ensuring compliance with updated regulatory documents (e.g., REGDOC-2.5.2, REGDOC-3.5.4, CSA N-series).
- Strengthening stakeholder collaboration for efficient regulatory adaptation.
- Implementing lessons from past VDR cases to optimize approval.

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