Nuclear Security Regulatory Framework Analysis for Small Modular Reactors in Canada and Abroad

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A PhD Level Submission

Summary

Small Modular Reactors (SMRs) are gaining global attention as a potential solution for future power plants due to claims of flexibility and cost effectiveness, while maintaining or increasing safety and security. With the change of design and the potential deployment in remote areas, however, challenges arise from a regulatory standpoint, to meet the safety and security regulations while maintaining economic feasibility.

This work comprises of a review of the nuclear security regulatory frameworks in place for SMRs in Canada, USA and the IAEA; how they compare to each other, and to those of large reactors. The goal is to gauge what needs to be adjusted in order to address the changes in design between the two reactor sizes.

Some key challenges concern the type of reactor, transportation of reactor components and fuel to remote areas, reduced security staff, and increased complexity of emergency planning and evacuation procedures.

1. Introduction

There has been a renewed interest lately in SMRs, which aim to introduce flexible, cost effective solution to building new power plants, with increased safety and security [1]. One of the main attractive features of SMRs is the ability to exploit the economy of multiples rather than the economy of scale, as well as utilizing self-financing and experience carried from one unit to the next.

With the change of design however, regulations on safety and security aspects might pose a challenge due to factors such as the modular construction, and the deployment in remote areas [2].

The idea of small reactors itself is not new; in fact, Canada has a long history of small reactor designs, both for power and research [1], such as ZEEP, NRX, NRU and others. The new concepts take into consideration many of the requirements that were not necessarily set into regulatory framework at the time these reactors were built. For example, one key goal of the new generation of reactors is increased proliferation resistance (such as in GEN-IV reactors), and the ability of SMRs to meet these requirements is still uncertain, due either to early deployment or known technical issues yet to be solved. An effective SMR regulatory framework is needed especially in the security aspects, due to the new designs, fuels, deployment areas, and waste storage.

2. SMR Characteristics

Small modular reactors have features and characteristics unique to their designs, most of which are meant to improve on previous designs and enhance performance, safety, and security. In the process, some of these features might prove challenging to current regulations, and require modifications in the framework to make these concepts practically and economically feasible.

Some of the main issues stem from the SMRs' small electrical output, which means the profit from the power plant is limited by the small amount of electricity sold. This leads to operators requiring reduced staffing for operations, maintenance, safety, and security, in order for the design to be economically viable. To achieve this, SMRs are designed from the very beginning with inherent safety and security features, meant to aid with reduced staffing while providing the same, or higher, level of safety and security to the power plant. Meanwhile, the current regulations do not allow for such reduction in staff for any power plant.

Some of the other challenges include issues related to modular construction, integrated components (sealed reactor cores), remote deployment, emergency planning and evacuations, and enrichment.

By moving to a modular construction, the process of manufacturing and transporting the components to the reactor site becomes simplified, however it also means transporting large amounts of fuel in the same time. This is more evident in cases where reactor cores are manufactured, fuelled, sealed and then shipped. While sealing the reactor core improves security, and increases the protection against tampering and sabotage, it can prove challenging for monitoring and maintenance operations. Some of the reactors are meant to operate continuously for multiple years before refuelling, and it is unlikely that no maintenance will be required on core components or instrumentation.

Those issues in mind, SMR designs do offer some benefits in the security aspects.

- The reactor size is typically much smaller than a large reactor, which means the target size is smaller.
- Due to simpler designs, and incorporated passive systems, inherent safety and security are increased.
- Smaller fission material inventory on site.
- Less frequent refuelling, and use of sealed cores reduces the chance of sabotage.

Globally, the European Union countries have a diversity of reactor types and designs, with different core coolants. This lead to some countries like France to establish a general framework for regulations and licensing, and accepting applications for new reactors on a case-by-case basis. As such, while there is an effort to unify the general regulations in the EU, creating special frameworks for SMRs as opposed to large reactors is not viewed as a concern for regulatory purposes. It appears only Canada and the USA are considering SMR licensing issues [3].

3. Regulatory Framework in Canada

The Canadian Nuclear Safety Commission (CNSC) is tasked under the Nuclear Safety and Control Act to regulate all nuclear-related facilities and activities in Canada.

The CNSC defines a small reactor for regulatory purposes, as having a thermal power lower than 200 MWth. The main regulatory document for such reactors is the RD-367: Design of Small Reactor Facilities, which applies to the reactors mentioned earlier. The document itself is very similar in requirements to the RD-337: Design of New Nuclear Power Plants, which applies to larger reactors, except for additional risk-informed mitigation in areas such as containment and confinement [4].

The principles in existing requirements and guidance apply to SMRs in general, however they may need revising for codes and standards in the case of water-cooled SMRs. Revising or supplementing the requirements is required for non-water-cooled SMRs, as well as developing new codes and standards, due to the fact that there is no structure in place for non-water-cooled reactors in Canada.

Current regulations for security and safeguards include 14 regulatory and guidance documents, encompassing, among others, such topics as: physical protection systems, explosive substance detection, nuclear response force, import and export, site access security clearance, and transportation security programs.

The content of these documents and the regulatory requirements are suitable for licensing activities involving SMRs. The issues arise from the need to relax these requirements in order for SMRs to be financially viable. The licensing process is essentially independent of the reactor size and technology, especially for security purposes. Most of the regulatory documents are applicable for any type of reactor and they cannot be relaxed for the purposes of SMRs. These include requirements such as security clearances for site access, transportation of nuclear material, etc…

The CNSC position on the matter is that in theory, all of the requirements shall remain unchanged, since they describe the minimum acceptable risk associated with nuclear power plant activities. Specific requirements such as staffing numbers may be relaxed if the operators and vendors can prove that the designs meet and exceed the minimum risk requirements. This is challenging in remote deployment situations where the off-site security force response time may be too high to adequately protect the facility from theft or sabotage. The security staffing issue is of great importance, since in a typical reactor, the security force is roughly 20-30% of the total workforce in the power plant [5].

A potential solution is to provide security and proliferation resistance inherent in design, such as utilizing a nuclear island located below ground.

The licensing process in Canada is generally an interactive process between the operators and the CNSC, whereby the CNSC lays out the regulatory requirements, documents and guidance, and the operators must prove that their designs are equivalent to or exceed the regulatory requirements. As such, part of building new regulations for SMRs involves the industry leading the discussion on developing solutions to arising issues particular to these new technologies, which will then be reviewed by the CNSC [4].

4. USA Regulatory Framework

For the USA, a similar structure is followed whereas the Atomic Energy Act [6] and the Energy Reorganization Act give the Nuclear Regulatory Commission (NRC) the responsibility of ensuring the peaceful uses of nuclear energy in the country. The NRC ensures safeguards and security by regulating licensees and providing security programs and contingency plans.

The security related regulatory documents are listed in the Code of Federal Regulations (CFR), Title 10, Chapter I [7], and include topics such as physical protection of nuclear materials and power plants, site access eligibility, facility security clearance and safeguards, material inventory and records, etc…

By comparing these documents with the Canadian regulatory documents, many similarities can be found in the overall structure and the requirements for security of nuclear materials and facilities. The USA has extra requirements for matters that do not apply in Canada, such as enrichment facilities.

Because the USA expects the SMRs designs to be mainly water cooled of the integrated PWR (iPWR) type, the NRC is actively assessing of the current security framework and how it applies to SMRs [8]. In addition, work is being done on assessing the suitability of the framework for non-water-cooled reactors, such as high-temperature gas-cooled reactors, fast reactors, molten salt reactors, etc…

The assessment by the NRC concluded that the current framework is adequate to be applied to iPWR designs, and operators must meet the criteria set in the CFR mentioned above. As for the non-LWR designs, the commission based its assessment on a limited knowledge base. The general requirements for security and safeguards remain applicable, however technology specific matters need to be assessed when a design is finalized and submitted for the NRC for approval. This is done to address issues such as different fuel composition and enrichment, and for material control and accounting.

SMR designers are allowed to propose alternative methods and approaches to meet the security regulatory requirements for any type of reactor (including current LWRs). In the case of most SMRs, this will mean reducing the reliance on staffing and replacing them with automated systems. These methods must prove to offer equivalent or higher protection and meet the requirements set in the CFR.

In cases where a design meets all the regulations but has some characteristics that favor increased security and may be subject to an exemption from a specific requirement, the vendor can apply for safety and security exemptions, to be reviewed by the NRC on a case-by-case basis, under CFR 50.12 and 52.7 [8].

For non-LWR designs, there is a need for a structure to be applied to reactors that vary in fuel types, coolants, moderators, enrichments, and system configurations. Applying the exemption process to these designs may prove complicated as the exemption applications might be numerous and complex in nature, resulting in significant effort and time to evaluate by the NRC and operators alike.

To address this issue, the NRC published SECY-04-0157 in which it proposed a technology-neutral risk-informed security framework to be applied to new reactor designs of any type. The acceptance criteria for approval of designs would require demonstration by the vendors that the design provides the same or higher level of protection for the reactor and public health, under the current regulations.

5. International Framework

Currently, there are no international regulatory regimes or infrastructure guidelines specific to SMRs. The IAEA however has made efforts in setting international standards and recommendations, which can be implemented by participating states in the regulatory structure. The IAEA introduced the concept of safeguards by design [9], which proposes introducing inherent security and safeguards at the earliest stages of design. This proved to be vital for SMR designers, since the economic feasibility of the reactors depends on reducing staffing requirements.

In addition to providing requirements, the IAEA also provides guidance and concepts on how to improve inherent security and safeguards [10]. Examples include:

- Introduce sufficient adversary delay times into the design: locate and configure vital components such that gaining access to these systems is extremely difficult and time consuming to an intruder.
- Reduce or eliminate the capability to destroy a target set from a single location.
- Construct barriers to be impossible to breach without detection.
- Provide adequate and reliable illumination for containment and surveillance.

- Ensure adequate storage capacity to provide unblocked viewing and inspection of nuclear materials.
- Use sealing systems for secure containment during periods of inactivity.

Some SMRs (based on specific designs, and/or deployment location) have characteristics that may impact the implementation of IAEA's international safeguards [10]. These potential issues include:

- Remote locations with limited access: adds time, cost and difficulty for safeguards inspectors to carry out unannounced inspections.
- Long-life cores (possibly sealed for years): reduced core access aids with the protection of fuel, however it conflicts with the IAEA annual physical inventory inspection.
- Enrichment: minimizing reactor size and maximizing time between refuelling means increasing the enrichment. Widespread adoption of these reactors would then mean an increased amount of enriched uranium in the world.

Implementing an international framework for SMRs is time and resource consuming, and requires the participation of regulators from countries to establish a common base for a technology-neutral approach to license and operate SMRs. The IAEA paves the way with recommendations and guidance documents, however international cooperation is required for a full and effective framework.

6. Concluding Remarks

A number of optimistic assumptions about economy, safety and security, must be realized in order for SMRs to be a viable solution. The premise of reducing cost is a very challenging one for SMR designers to accomplish while meeting the current legal requirements for safety and security. As such, new designs must prove to have a high level of inherent safety and security measures.

The current security regulatory frameworks in Canada and the USA apply the same stringent requirements to SMR designs, while acknowledging the need for improvement and development of codes and standards for new technologies.

In Canada, the CNSC framework is flexible and technology-neutral. In the case of SMRs, the industry must lead the discussion on how the new designs deal with safety and security issues, and the overall process is an interactive one between the operators and the regulator.

In the USA, the NRC is taking an active approach in assessing the current regulatory framework for SMRs. The proposed methods include creating new technology-neutral structures for licensing non-LWRs, and/or allowing designers and applicants to apply for exemptions from specific requirements, to be evaluated on a case-by-case basis for LWR designs.

The IAEA proposed recommendations for security requirements for SMR designs, however there is no international framework yet and it is up to each state to choose whether to enforce these requirements in the legal framework.

7. Works Cited

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