PHYSICAL SECURITY FOR SMALL MODULAR REACTORS

Lead Writer – Mark S. Campagna
Assistant Writer – Walter Sawruk

American Nuclear Society (ANS)

TABLE OF CONTENTS

1.0 INTRODUCTION

This paper discusses the issues of security risk management and potential risk mitigation strategies associated with the deployment of small modular reactors in the United States and abroad. It is crucial that these issues be addressed early in the small modular reactor lifecycle to ensure superior and reliable security and safety performance and maximum economic efficiencies in the design, fabrication, installation, and lifetime operation of small modular reactors worldwide.

2.0 BACKGROUND

The worldwide deployment of peaceful nuclear technology is predicated on conformance with the Nuclear Non-Proliferation Treaty of 1972 (NPT) and with modern standards for physical protection. Under the NPT, countries have relinquished pursuit of nuclear weapons in exchange for access to commercial nuclear technology that could help them grow economically. Realistically, however, most nuclear technology has been beyond the capacity of the NPT developing countries to afford. Even if the capital cost of the plant is managed, the costs of the infrastructure and the operational complexity of most nuclear technology could remove it as a viable option for consideration by the nations who need it the most.

This paper examines the functional requirements for both small modular reactors for deployment in the United States and also for those planned for export to other world countries. To enable proper export of U.S. technology, the highest standards for such an important design/engineering/performance issue as

International Atomic Energy Agency (IAEA) safeguards to detect diversion or undeclared production of nuclear materials, and physical protection to prevent theft and radiological sabotage, need to be considered early and thoroughly; this is especially applicable for small modular reactors since much of the assembly work may be done in a factory setting prior to shipment.

A new class of small modular reactors has been specifically designed to meet the electrical power, water, hydrogen, and heat needs of small and remote users/communities and of medium to large industrial applications. These reactors feature small size, a long refueling interval, and simplified operations, all of which assist in minimization of security threats. Sized in the 10- to 50-MW(electric) range (very small) and up to the 300-MW(electric) range (small to medium), these reactors utilize factory modularization for rapid site deployment and assembly of single or multiple reactor “modules,” placing an even greater premium on design standardization.

With large (mostly light water) 1000-MW(electric)+ reactors limited to the two to three dozen heavily industrialized countries, it is evident that distributed power using small modular reactors could be a very feasible solution to addressing the energy needs of the remainder of the world's nations in both the short and long terms provided issues such as physical security can be successfully addressed.

Furthermore, to emphasize the importance of maintaining high U.S.-based standards, any Small and Medium Sized Reactor (SMR) Nuclear Power Plant (NPP) manufactured by licensee [e.g., via a U.S. Nuclear Regulatory Commission (NRC)–issued Manufacturing License (ML)] may not be exported unless the ultimate customer meets all U.S. legal and regulatory export requirements, including 10 CFR 110 (Ref. 1) and 10 CFR 810 (Ref. 2). An export license should be complementary to the ML in an integrated fashion and should address all Federal export control requirements, not only those of the NRC but also those of the U.S. Department of Energy (DOE), U.S. Department of Commerce, and U.S. Department of State. [NOTE: The ML topic is the subject of another paper for the American Nuclear Society (ANS) President’s Special Committee on SMR Generic Licensing Issues (SMR Special Committee): “Utilization of NRC Manufacturing License for Small Modular Reactors”].

3.0 PROBLEM/ISSUE STATEMENT

The extent and relevance of this issue is considerable for SMR-NPPs; this since the worldwide deployment of peaceful nuclear technology is predicated on conformance with the NPT. We must consider various U.N. Resolutions (e.g., 1540) and the impact of other international agreements (e.g., Bilateral 123 Nuclear Technology Agreements between the United States and other countries). "123" refers to Section 123 of the U.S. Atomic Energy Act of 1954, which provides the legal framework for peaceful nuclear energy commerce. The United States has more than 30 such agreements in place with key partner nations. It therefore becomes imperative that the issues of nuclear proliferation resistance and physical protection of SMRs be addressed prior to addressing other key concerns such as fuel, waste, and economic/legal/political-stakeholder issues.

Since SMRs are generally in the early stages of development, a significant opportunity exists to affect designs in a way that (1) minimizes the future need for either substantial security forces, excess engineered devices, and/or complex procedural methodologies and (2) allows for the design optimization needed for more effective deployment of new applications. Early-stage design input can compensate in part for later possible design vulnerabilities against intentional acts of sabotage or theft.

Therefore, IAEA safeguards and physical security of the SMR must be included in the early design phase in order for the SMR to be an economically feasible solution when built. It is imperative that any SMR design demonstrate proof of requisite high levels of safe survivability from all credible threats, including malevolent terrorism, theft, or aircraft impact. An approach such as the proliferation resistance and physical protection evaluation methodology developed for Generation IV (GEN-IV) nuclear energy systems (Ref. 3) offers an attractive framework for application to SMRs. Stakeholders must understand the risks (i.e., financial and functional); the actual level of threat and required protection must be carefully assessed and understood by the appropriate qualified engineers/designers during very early stages of design/engineering.

4.0 DISCUSSION AND ACTUAL WORK

The operational experience of the existing fleet of Light Water Reactors (LWRs) provides valuable data that can be utilized in the development of sound design decisions for the next wave of advanced reactors and in the establishment of a well-structured approach to providing an appropriate security posture for the large LWRs within the U.S. National Response Framework (Refs. 4, 5, and 6). For other advanced reactors, including SMRs, that are either non-LWR based (e.g., gas- or liquid metal–cooled reactors) or small LWRs, designs are sufficiently different in their safety and operating characteristics such that the means to address safeguards and security requirements should be carefully evaluated to take into consideration the different design characteristics in satisfying ultimate performance objectives.

SMR developers can benefit from the advantages of favorable characteristics such as (1) small (target) size, (2) greater use of inherent security characteristics and passive safety features, and (3) smaller fission product inventory on a per-reactor basis. Conversely, with modular reactors a larger number of reactors must be protected. The objectives outlined in this paper are intended to meet or exceed the revised design basis threat (DBT) and requirements for enhanced security features set forth by the NRC in the recently revised 10 CFR 50.150 (Ref. 7), 10 CFR 73.1 (Ref. 8), and 10 CFR 73.55 (Ref. 9) without diminishing either the safety simplicity or economic feasibility/opportunities of SMRs. Since security requirements will most likely increase over the lifetime operation of the plants, it would be prudent for SMR designers to consider costs versus benefits of incorporating some additional design margins or provisions in the conceptual phase to lessen the impact of future changes to the DBT.

In order to address security design issues that provide for design optimization and maximum economic feasibility, the following areas were considered:

- *use of modern tools*: evaluation of risk-informed and performance-based methods such as are already being utilized quite effectively in analogous physical security applications by the DOE and U.S. Department of Defense to explore design functional vulnerabilities to defined security threats unique to individual SMR designs (Ref. 10, 11, and 12). Collaboration with industry standards bodies to formulate consensus methods for utilizing processes for achieving this goal (Refs. 13 and 14)

- *planning conceptual advantage*: physical separation of active systems to the extent practical to avoid limiting localized consequences from security breaches or internal acts or external damage

- *consideration of remote/passive features*: maximization of inherent characteristics and passive features that do not depend on immediate or short-term operator actions to assure extra protection, therefore deriving beneficial time delay advantage when analyzing effects on nuclear Systems, Structures, and Components (SSCs) or mitigating the consequences of security-driven transients or accidents

- *identification of improvements to redundancy*: arrangement or design of multiple reactor modules such that no single security threat is capable of creating an unacceptable radiological response in more than one reactor unit at a time

- *minimization of reliance on personnel*: careful examination of dependencies on reactor operator actions during any security-induced transient or event to assure that plant and public safety requirements are achievable with desired small staffing levels, without unnecessary dependence on operator actions for the first 24 to 72 hours

- *evaluation of increased utilization of remote and automated technology*: allowance for reducing or eliminating internal security staff requirements for normal operations and maintenance conditions that do not add to the security posture

- *consideration of geo-location and other functional effects*: establishment of a standard approach to integrating security requirements within the evolving requirements for large industrial facilities where SMRs are used as a process heat source.

5.0 CONCLUSIONS

1. **In order to address security design issues that provide for design optimization and minimize operational staff requirements, the SMR physical security approach should include the following five basic objectives:**

   (1) **Rely on government response for SMR facilities with vital assets underground or otherwise well protected.** Shallow burial or a hardened structural design provides excellent protection against large explosive weapons and aircraft impact as well as an excellent means of enhancing security system effectiveness against sabotage. Application of the traditional multilayered defensive approach of detection, deterrence, delay, and defeat can be used effectively for physical protection of SMRs. Detection, deterrence, and delay concepts must be integrated into the early design phase of the facility in order to provide sufficient lead time for government response.

   (2) **Plan for DBTs that will evolve over facility lifetime.** Significant increases in the DBT should be expected and planned for starting at the conceptual design phase so as to minimize impact on operations and overall facility configuration and design. For example, establish a perimeter with sufficient standoff for protection against explosive threats in excess of the DBT and incorporate line-of-sight barriers into the design for protection against standoff weapons.

   A definitive DBT, including aircraft impact, is necessary at the outset of the conceptual design phase in order to fully realize the potential benefits of integrating design, security, and preparedness. Although aircraft impact is sometimes treated separately from other physical security threats, it differs only in the scale of potential consequences and likelihood of occurrence from a facility design viewpoint. Mitigation measures developed for protection against physical security threats are likely to also contribute toward mitigation of the effects of the aircraft impact threat (Ref. 13). NRC's policy issue information statement SECY-10-0034 (Ref. 15) conflicts with this desired industry approach in that it suggests SMR designers determine the DBT for NRC's review and acceptance and it also implies that the NRC may impose supplemental acceptance criteria for non-LWR designs for aircraft impact after initial NRC reviews.

(3) **Risk-informed licensing approach.** A risk-informed and performance-based licensing approach including physical security to the extent practical has the potential to provide a more balanced physical security system than the current prescriptive approach to defending against the DBT.

(4) **Design the facility with limited access points and multiple passive barriers.** A defense-in-depth approach incorporating multiple passive barriers and limited access points to vital areas at the conceptual design stage will enhance overall security system effectiveness. Passive safety systems that do not require routine access for surveillance and maintenance can be hardened to provide long passive delay times.

(5) **Security system technology.** Significant advances in security system technology and countermeasures will most likely occur over the facility lifetime. Plan for security system technology obsolescence during the conceptual design phase. Build in redundancy and separation of systems to allow for future system overhaul or replacement with minimal need for compensatory measures.

2. **SMR-NPPs will require finalized up-front plans for advanced physical security implementation methods.** The performance spectrum and tools available for 21st century NPP design, engineering, and operation will be used for SMR-NPPs. Advanced planning and conceptual engineering implements would include objectives outlined in the points discussed above. Definitive regulatory requirements will be necessary at the outset to minimize licensing process uncertainties and unnecessary overdesigns and redesigns. Imposition of new criteria during the licensing review process (Ref. 15) would be counterproductive.

3. **Successful SMR-NPP security performance outcomes will depend upon advanced measurement tools/techniques.** Analysis methods should be utilized that result in more accurate measurement of effects. Use of risk-informed analysis can be very accurately and comprehensively applied to the limited number of vital SSCs and the smaller geo-radiological footprint of an SMR-NPP; this could result in a much higher expectation of more reliable accuracy to ensure proper deterministic outcome.

4. **SMRs by their very nature may require new rule or regulatory guidance**. Upon examination of the various technologies utilized in the design of SMRs, it is evident that there is a substantial difference between these new designs and existing NPP technology sufficient to justify a "bottoms-up" assessment of such important issues as physical protection and safety. Basic parameters such as operating pressure/temperature; fission product inventory; and type-nature of coolant, materials, and moderator would appear to require further detailed assessment.

6.0 RECOMMENDATIONS

1. A new NRC Regulatory Guide is needed to address specific design aspects of the SMR-NPPs and to provide guidance for physical security and IAEA safeguards to assist engineers/designers and SMR developers.

2. The SMR Special Committee recommends using and exploring the Design Centered Working Group (DCWG) approach to reflect proactive improvement of detail for like reactor designs.

3. The use of automation, remote plant operations, and remote security for SMRs utilizing information relative to similar use in both the government/military and civilian commercial operations should be evaluated for applicability to SMR designs.

7.0 REFERENCES

1. *Code of Federal Regulations*, Title 10, "Energy," Part 110, "Export and Import of Nuclear Equipment and Material," U.S. Nuclear Regulatory Commission.

2. *Code of Federal Regulations*, Title 10, "Energy," Part 810, "Assistance to Foreign Atomic Energy Activities," U.S. Department of Energy.

3. "Evaluation Methodology for Proliferation Resistance and Physical Protection of Generation IV Nuclear Energy Systems," OECD Nuclear Energy Agency/Generation IV International Forum, Rev. 5 (Sep. 30, 2006).

4. *Code of Federal Regulations*, Title 10, "Energy," Part 73 Series, "Physical Protection of Plants and Materials," U.S. Nuclear Regulatory Commission.

5. SECY-03-0047, "Policy Issues Related to Licensing Non-Light Water Reactor Designs," U.S. Nuclear Regulatory Commission (Mar. 28, 2003).

6. SECY-05-0120, "Security Design Expectations for New Reactor Licensing Activities," U.S. Nuclear Regulatory Commission (July 6, 2005).

7. *Code of Federal Regulations*, Title 10, "Energy," Part 50, "Domestic Licensing of Production and Utilization Facilities," Sec. 50.150, "Aircraft Impact Assessment," U.S. Nuclear Regulatory Commission.

8. *Code of Federal Regulations*, Title 10, "Energy," Part 73, "Physical Protection of Plants and Materials," Sec. 73.1, "Purpose and Scope," U.S. Nuclear Regulatory Commission.

9. *Code of Federal Regulations*, Title 10, "Energy," Part 73, "Physical Protection of Plants and Materials," Sec. 73.55, "Requirements for Physical Protection of Licensed Activities in Nuclear Power Reactors Against Radiological Sabotage," U.S. Nuclear Regulatory Commission.

10. SECY-08-0099, "Final Ruling – Power Reactor Security Requirements (RIN 3150-AG63)," U.S. Nuclear Regulatory Commission (July 9, 2008).

11. SECY-08-0152, “Final Rule – Consideration of Aircraft Impacts for New Power Reactors (RIN 3150-AI19),” U.S. Nuclear Regulatory Commission (Oct. 15, 2008).

12. SECY-09-0056, “Staff Approach Regarding a Risk-Informed and Performance-Based Revision to Part 50 of Title 10 of the Code of Federal Regulations and Developing a Policy Statement on Defense-in-Depth for Future Reactors,” U.S. Nuclear Regulatory Commission (Apr. 7, 2009).

13. C*ode of Federal Regulations*, Title 10, “Energy,” Part 50, “Domestic Licensing of Production and Utilization Facilities,” and Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants,” U.S. Nuclear Regulatory Commission; Final Rule, 74 FR 28112 (June 12, 2009).

14. NGNP Licensing Plan PLN-3202, Idaho National Laboratory (June 26, 2009).

15. SECY-10-0034, “Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs,” U.S. Nuclear Regulatory Commission (Mar. 28, 2010).