A Study on the Regulatory Requirements of Nuclear Energy Systems in the Area of Proliferation Resistance

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1. Introduction

KAERI has been developing potential regulatory requirements of nuclear energy systems in the area of proliferation resistance (PR) based on the INPRO methodology. This paper presents general concepts and fundamentals, including relevant issues, of proliferation resistance that are to be considered in the licensing process (design and operation) of nuclear energy systems.

2. Concepts and Fundamentals of Proliferation Resistance

The INPRO PR methodology is an internationally validated tool for assessing PR of innovative nuclear energy systems (INSs) for sustainability [1]. It provides a framework for the qualitative evaluation of the proliferation resistance of nuclear reactors and fuel cycles at State level, nuclear energy system (NES) level, and facility level including facility specific pathway level [2]. It defines a Basic Principle for proliferation resistance which requires five user requirements (URs) to be fulfilled by the State, the designers and operators to achieve users' acceptance for sustainability of a given INS.

Proliferation Resistance is that characteristic of a nuclear system that impedes the diversion or undeclared production of nuclear material, or misuse of technology, by States in order to acquire nuclear weapons or other nuclear explosive devices [3]. Observing proliferation resistance in the licensing process of INSs does not mean that it prevents technologies that have been proven to be safe, secure and economical (following the INPRO definition of sustainability) but to assure that the system will "continue to be an unattractive means to acquire fissile material for a nuclear weapons program".

3. Regulatory Requirements for Proliferation Resistance

The INPRO URs set out the measures to be taken by technology developers or designers, by owners/ operators of nuclear facilities, and by the State to ensure fulfillment of the basic principle to which they relate in regard to the design requirements. For each UR, a Criterion (CR) (or more than one) is required to enable the INPRO assessor to determine whether and how well a given user requirement is being met by a given INS. An INPRO criterion consists of an Indicator (IN)and an Acceptance Limit (AL). Indicators may be based on a single parameter, an aggregate variable, or a status statement.

The degree of proliferation resistance results from a combination of, inter alia, technical design feature, operational modalities, institutional arrangements and safeguards measures. To minimize the proliferation concerns associated with nuclear energy systems, intrinsic proliferation resistance features and extrinsic proliferation resistance measures shall be implemented throughout the full life cycle for innovative nuclear energy systems, meaning from initial planning through operation to the decommissioning stage, for innovative nuclear energy systems.

Regulatory requirements on PR in the licensing process of nuclear energy systems are part of States' commitment to non-proliferation. They should include obligations in relation to all those above-mentioned four categories, and should answer fundamental questions about commonly used criteria, such as:

- Nuclear material attractiveness: can the nuclear material in the NES be easily used in a nuclear weapons program?
- Nuclear technology attractiveness: can the NES be misused for the production of nuclear material that could be easily used in a nuclear weapons program?
- Difficulty and detectability of diversion/misuse: does design and operation of the NES facilitate the implementation of IAEA safeguards? Can the NES be safeguarded effectively and efficiently by the safeguards authorities (accountability, amenability for C/S measures and other monitoring, transparency of design and processes, etc.)?
- Optimization of design: does design and operation of the NES provide cost-efficient PR both to the facility operator and the safeguards authorities and compatibility with other design considerations as safety, security, and operation?
- Institutional arrangements: do institutional structural arrangements like multinational ownership or commercial arrangements that control access to and use of nuclear material support facility and enterprise undertaking to PR?

3.1 Attractiveness of Nuclear Material and Technology

In case of attractiveness of nuclear material and

technology, the indicators are nuclear material quality, quantity, classification and technology used in NES, and the acceptance criteria are that nuclear material characteristics and technology considered in design of NES should be low enough based on expert judgment. The criteria are somewhat ambiguous, but the procedure to draw expert judgment could be drawn in the regulatory requirement.

3.2 Difficulty and Detectability of Diversion

For the difficulty and detectability of diversion of nuclear material and misuse of technology, the indicators are accountability for IAEA safeguards, amenability of containment of surveillance (C/S) at the nuclear facility, detectability of nuclear material, difficulty to modify process and facility design, and detectability of misuse of technology or facility. These indicators can be evaluated using parameters which can be defined in the regulatory requirements for the licensing process, and the acceptance criteria could be that the evaluation results for the indicators are equal or better than existing facility meeting international state of practice based on expert judgment.

In addition to the difficulty and detectability of diversion, the design and operation of NES should facilitate the implementation of IAEA safeguards, defectively and efficiently in terms of accountability, amenability of C/S measures and other monitoring, including transparency of design and processes, etc.

The Acceptance Criteria allow to answer the fundamental PR related questions and show strengths and weaknesses regarding proliferation resistance of an INS. Therefore, the regulatory requirements should be based on the acceptance limits of each user requirement, and the designer is supposed to provide the justification that the NES meets the acceptance limits in those relevant areas.

3.3 Multiplicity and Robustness of Proliferation Barriers

User requirement 4 says that innovative nuclear energy systems should incorporate multiple proliferation resistance features and measures. However, the assessment of this user requirement requires an acquisition/diversion pathway analysis to be performed by PR experts, and to fulfill this requirement, all plausible acquisition paths should (or can) be covered by extrinsic measures on the facility or State level and by intrinsic features which are compatible with other design requirements. Regarding the robustness of barriers against proliferation, it is measured by determining if, and how, the safeguards goals of the safeguards authorities can be met effectively and efficiently.

3.4 Optimization of Design

UR5 says that the combination of intrinsic features and extrinsic measures, compatible with other design considerations (in the design and engineering phase) should be optimized to provide cost-efficient proliferation resistance. The developer should consider proliferation resistance as soon as sufficient technical information is available in the development of a new INS. This should be no later than the conceptual design stage and could begin earlier as fundamental design concepts are discussed. Early consideration provides opportunity for the design to be guided, in part, by proliferation resistance, before significant design decisions are finalized.

The costs for the introduction of the new intrinsic features and extrinsic measures or the modification of existing intrinsic features and extrinsic measures are to be considered. The cost effectiveness analysis should be implemented by the designer to show that cost effective features have been employed taking into account a balance between facility and verification costs

3.5 Institutional Arrangements

The government may support the nuclear industry in establishing institutional structural arrangements such as multinational ownership or commercial arrangements that control access to and use of nuclear material support facility and enterprise undertaking to PR that are capable to enhance proliferation resistance. However, this should not be a mandatory measure in the licensing process.

4. Conclusion

The study indicates that reasonable guidelines can be developed based on the concepts, principles and fundamentals of proliferation resistance. The regulatory body is responsible for drafting and establishing regulatory requirements for the licensing process (design, operation, and maintenance) of nuclear energy systems, in line with State's commitments, obligations and policies regarding non-proliferation. The requirements would include enforcement ordinance, enforcement regulations, including technical codes and standards for design, operation, and maintenance, in the area of proliferation resistance of an NES.

5. REFERENCES

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