Transactions of the Korean Nuclear Society Spring Meeting
Pyeongchang, Korea, May 27-28, 2010

Status of Methodology Development for the Evaluation of Proliferation Resistance

YongDeok Lee*, Won-il Ko, Jung Won Lee
Korea Atomic Energy Research Institute, P.O. Box105, Yusung, Daejon, Korea 305-600
**Corresponding author: ydlee@kaeri.re.kr*

1. Introduction

Concerning the increasing energy demand and green house effect, nuclear energy is now the most feasible option. Therefore, recently, oil countries even have a plan to build the nuclear power plant for energy production. If nuclear systems are to make a major and sustainable contribution to the worlds energy supply, future nuclear energy systems must meet specific requirements. One of the requirements is to satisfy the proliferation resistance condition in an entire nuclear system. Therefore, from the beginning of future nuclear energy system development, it is important to consider a proliferation resistance to prevent the diversion of nuclear materials. The misuse of a nuclear system must be considered as well. Moreover, in the import and export of nuclear system, the evaluation of the proliferation resistance on the nuclear system becomes a key factor

The INPRO (International Project on Innovative Nuclear Reactors and Fuel Cycles) program initiated by the IAEA proposed proliferation resistance (PR) as a key component of a future innovative nuclear system (INS) with a sustainability, economics, safety of nuclear installation and waste management[1]. The technical goal for Generation IV (Gen IV) nuclear energy systems (NESs) highlights a Proliferation Resistance and Physical Protection (PR&PP), sustainability, safety, reliability and economics as well[2].

Based on INPRO and Gen IV study, the methodology development for the evaluation of proliferation resistance has been carried out in KAERI. Finally, the systematic procedure for methodology was setup and the indicators for the procedure were decided[3]. The methodology involves the evaluation from total nuclear system to individual process. Therefore, in this study, the detailed procedure for the evaluation of proliferation resistance and the newly proposed additional indicators are described and several conditions are proposed to increase the proliferation resistance in the future nuclear system.

The assessment of PR is inherently qualitative and it is difficult to quantify the evaluation result. Therefore, the new evaluation model needs to develop the methodology how to quantify the evaluation results with credibility.

2. Evaluation Methodology

Several barriers are introduced in the evaluation of nuclear system for proliferation resistance. First, extrinsic barriers are introduced based on States' commitments and obligation and institutional arrangements related to nuclear energy systems. For States' commitments and obligation, there are several international treaties, convention and agreements. Therefore, extrinsic barriers involve State or institution intension for proliferation resistance.

Several factors from material itself influence on the use of nuclear material as an explosive, for example, critical mass, isotopic content, chemical form, heat generation, spontaneous neutron generation and gamma emission[4,5]. Heat generation and radiation emission influence on the quality of weapon explosion. Therefore, intrinsic barriers involve the feature of material itself for the proliferation resistance.

Safeguards apply facility information, nuclear material detection method, containment and surveillance, nuclear material accounting information, and inspection/in-field verification. Generally, for Pu and U233, 2~4 kg error has acceptance in the system. For U235 with high enrichment, 9~18 kg has acceptance limit[4]. Safeguards barrier involves the international monitor for the proliferation resistance.

Additionally, nuclear material pathway analysis was added for the diversion at each process. By analyzing the possible diversion pathways at each process in advance, the nuclear material diversion can be isolated by applying more barriers in the process. Extrinsic, intrinsic and safeguards barriers are used in the pathway analysis.

3. Additional Indicator Development

The newly developed indicators are introduced for extrinsic and intrinsic barriers. For extrinsic indicator, compliance on the obligation of State and institution is very important after joining treaty or agreement. Therefore, whether or not compliance will evaluates the potential on nuclear material diversion. However, the quantification of evaluation for compliance is not simple and the conclusion for the future diversion potential from the current state evaluation is not easy.

Time indicator is considered to obtain 1SQ (significant quantity) nuclear material amount. This indicator is very important for the delayed and continuous small amount acquisitions. Therefore, applying new indicator to evaluate the acquisition of 1SQ amount as a function of time gives the improved evaluation results for nuclear material diversion. This is directly applicable in the process. For plutonium, the minimum required time to separate plutonium is less than 1 week in the metal and oxide form, 4-6 weeks for Pu ceramic and reactor fuel, 8weeks for spent fuel.

Therefore, qualitatively, 1 month, 2 months and more than 2 months are possible classification.

4. Criteria for Proliferation Resistance

In the designed evaluation methodology, the systematic approach is suggested for the development of evaluation methodology, which is not the way of only using barrier itself but a combination of barriers and a diversion pathway analysis for proliferation resistance. For increasing the proliferation resistance in the future nuclear system, several criteria are proposed.

- minimizing plutonium accumulation in the process
- establishment of monitoring system by safeguards
- increasing intrinsic barrier by adding minor actinide rather than pure plutonium
- no plutonium conversion
- cooperation of intrinsic, extrinsic and safeguards barriers
- all possible scenario development for diversion
- minimizing transportation of nuclear material
- long term reactor burning or totally closed small reactor type

Production of weapons material can be made directly in a nuclear power plant, enrichment facility and reprocessing facility. Diversion of material can occur at a specific point in the material flow of nuclear system, for example, transportation, production facility and storage facility. In a reactor site, fuel storage site, fuel handling area, reactor irradiation report, spent fuel handling area, fuel pool storage area and dry storage area are the most important point for the pathway analysis.

5. Results and Conclusion

The design of methodology was completed for the evaluation of proliferation resistance. Several barriers are classified and the features are described for the evaluation of proliferation resistance. Proliferation resistance analysis is intended to be performed from the earliest stages of the system design where initial flow diagrams and physical arrangement drawings are developed with safety analysis. The designer can introduce barriers that systematically make these pathways less attractive.

In the evaluation, qualitative and quantitative methodologies are used. For the qualitative evaluation, grouping and importance like strong, medium and weak, are used and yes or no is another way. For the quantitative evaluation, weighting of each indicator importance is another approach. However, weighting value has the consensus.

The integration of system and process evaluation is the final step. The eventual evaluation of proliferation resistance on the system is the integration of all individual indicators, qualitative and quantitative. Therefore, the way to merge the results is important, but the importance on each indicator is not decided yet. Therefore, technical and objective approach is necessary for the integration of results

Acknowledgement

This work is performed under the auspices of Korea Ministry of Science and Technology as a long-term R&D project.

REFERENCES

[1] International Atomic Energy Agency; Methodology for the assessment of innovative nuclear reactors and fuel cycles; Report of Phase 1B (first part) of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO); IAEA TECDOC-1434; IAEA; Vienna; 2004.

[2] NERAC(DOE), Technical Opportunities to Increase the PROLIFERATION Resistance of Global Civilian Nuclear Power Systems (TOPS), Jan., 2001.

[3] YongDeok Lee, and Jung Won Lee, Methodology Development for The Evaluation of Proliferation Resistance, Korean Nuclear Society Fall Meeting, Oct.30, 2008, Pyeongchang.

[4] International Atomic Energy Agency; INPRO Manual for the area of Proliferation Resistance; IAEA-TECDOC-to be updated; Volume 5; IAEA; Vienna; 2007.

[5] The Proliferation Resistance and Physical Protection Evaluation Methodology Expert Group of the Generation IV International Forum, Evaluation Methodology for Proliferation Resistance and Physical Protection of Generation IV Nuclear Energy System, Revision 5, Sept, 2006.