Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 19-20, 2022

PRPP activities of Generation-IV International Forum (GIF)

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1. Introduction

The technology goals for Generation IV nuclear energy systems [1] highlight proliferation resistance and physical protection (PR&PP) as one of the four goals along with sustainability, safety and reliability, and economics. Giving this PR&PP goal such high visibility emphasizes the need for a sound evaluation methodology to guide future system evaluation and development. The PR focuses on providing the assurance that Generation IV systems are the least desirable ones for its diversion or undeclared nuclear materials. The PP portion of the goal ensures that Generation IV Systems will be robustly resistant to theft and sabotage.

2. Previous Work for PR&PP of GIF

Since publication of the methodology developed by the Evaluation Methodology Group during the Generation IV Technology Roadmap [2], systematic work has improved evaluation methods. One example of such work is the study Guidelines for the Performance of Nonproliferation Assessments, issued by the U.S. Department of Energy (DOE)/ National Nuclear Security Administration (NNSA), which provides the basis for the current PR&PP methodology. More detailed background information is included in GIF PRPP report [3], which summarizes the metrics used in past assessments of PR, and which reviews past assessments of PP. The following sections summarize those studies.

2.1 Proliferation Resistance Activities

Consideration of PR began in the 1970s with the International Nuclear Fuel Cycle Evaluation (INFCE) carried out by the IAEA and the Non-proliferation Alternative Systems Assessment Program (NASAP) carried out by DOE. Both NASAP and INFCE were more focused on identifying positive directions for fuel cycle development to minimize proliferation risks rather than on developing comprehensive means for evaluating that risk. The conclusion of these studies was that no technological arrangements would be immune to proliferation in the face of a State determined to obtain a weapons capability [4] [5] [6].

Studies of PR have covered a wide scope, including considering dedicated and civilian facilities and assessing individual facilities and entire fuel cycles. A comprehensive review of past work and examination of PR assessment can be found in documents by Krakowski [17], NPAM [18] and Cojazzi and Renda [19].

Another form of decision analysis based on the assessment of barriers to proliferation emerged in 1996 with the Proliferation Vulnerability Red Team. A similar approach was cited by the Task Force on Technological Opportunities to Increase the Proliferation Resistance of Global Civilian Nuclear Power Systems (TOPS) of the U.S. DOE, Nuclear Energy Research Advisory Council (NERAC). The TOPS task force formulated a set of qualitative attributes relevant to PR but made no attempt to perform quantitative or comparative assessment based on these attributes [7].

Although early probabilistic assessments of nuclear material diversion were published in the late 1980s, systematic probabilistic evaluations of threats and vulnerabilities remained in the background until the latter half of the 1990s, and formal probabilistic risk analysis approaches were not proposed until the new millennium. Elaborating on Safeguards Logic Trees developed by Hill [8], Cojazzi and Renda [9] investigated the potential of the fault tree technique to identify all possible acquisition scenarios in a given nuclear fuel cycle and their quantification [9].

In 2004, the Blue Ribbon Panel of the USDOE Advanced Fuel Cycle Initiative examined the PR of a number of different alternative fuel cycles (PUREX/MOX, UREX, DUPIC, and Inert Matrix Fuel) involving current light-water reactors [10]. The assessment relied on a MAU analysis methodology developed by Charlton [20].

2.2 Physical Protection Activities

Although the assets to be protected, consequences of the attack, and ways to detect, delay, and respond to an attack may differ, the basic principles are subjected to protect a facility against sabotage or theft, whether it is a nuclear energy system, a petrochemical infrastructure, a water treatment plant, a financial center, or a military site. Consequently, early development of methods for assessing PP predates the nuclear industry. Although probably not recognized as such in early times, scenario analysis has been used for centuries to plan defenses. With the advent of modern analytical techniques, the evaluation of PP has become structured and formalized.

The systematic analytical basis of PP is more mature than that of PR, relying on the principles of probabilistic risk assessment. In this treatment, the fault tree structure is commonly used to define threats, evaluate system response, identify system vulnerabilities, and rank risks. As with PR, much of the data involved are obtained subjectively. Thus, the resulting analyses are sometimes qualitative and reflect belief rather than objective analyses. However, they provide an integrated summary of the competing threats and risks and have led to the use of metrics to compare alternative facility designs and threat responses. The analysis has also provided a framework to specify, in a technology-neutral fashion, the performance requirements of the systems examined [11] [12].

Current practice in the evaluation of the potential consequences of hypothetical threats to a facility is to postulate a Design Basis Threat (DBT), which is believed to provide a bounding characterization of the possible challenges to the facility. This DBT could be applied to define the threat and obtain its reliable likelihoods. The DBT concept was developed in the 1970s in work by Sandia National Laboratories (SNL) and U.S. Nuclear Regulatory Commission (NRC). SNL, in conjunction with representatives from Germany, the United Kingdom, France, and the IAEA, has conducted numerous workshops on the creation and use of the DBT since 1999. In October 2000, representatives from these States met under the coordination of the IAEA and created an international standard model for the development and use of a DBT [14].

2.3 International Cooperation Activities

The International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) is an IAEA driven concurrent initiative developing a methodology for the holistic assessment of nuclear energy systems. The INPRO assessment methodology [15] is based on a hierarchical structure of Basic Principles, User Requirements, and Criteria consisting of Indicators and Acceptance Limits. Indicators are compared with corresponding acceptance limits, and judgement is made regarding the NES's capability to meet or exceed the criteria and user requirements.

An INPRO assessment covers several different areas: Economics, Environment, Waste Management, Safety, Infrastructure, and Proliferation Resistance. Implementation manuals are under development in all these areas, including the new area of Physical Protection. Although the GIF PR&PP and INPRO evaluation methodologies differ in their implementation, GIF and INPRO share in their objectives to ensure that NESs of the 21st century are sustainable, safe and reliable, and economically viable while minimizing their risk of contributing to nuclear weapons proliferation and maximizing their robustness against theft and sabotage.

The development of both approaches benefits from the exchange of information and the links provided by participants in both efforts. An update of the INPRO work is given in the publication IAEA-TECDOC-CD-1575 [16]. The publication covers all areas of INPRO assessment, including proliferation resistance and physical protection.

3. Conclusions and Perspectives

Considerable work has been done to assess PR and PP robustness. The two subjects have traditionally been studied separately. Proliferation is commonly viewed as an international concern, and past work on a wide range of PR assessments is widely available. However, because PP is regarded as a State's security and sovereignty concern, much of the work is controlled or classified. Despite this, systematic analytical assessment similar to the evaluation framework discussed in this report is more mature for PP than for PR.

The GIF has been operating the PRPP working group (PRPPWG) that works on the PR&PP methodology for system designers, safeguards experts, and policy makers to better understand. The PRPP reports reflecting the specific characteristics of six GEN-IV reactors, SFR, VHTR, LFR, GFR, SCWR and MSR are expected to be published and updated.

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