Development of Risk Assessment Measures for Physical Protection of Nuclear Facilities

Hosik Yoo, Sung-Woo Kwak, Sung-Soon Chang, Jae-Kwang Kim, Jung-Soo Kim and Wan-Ki Yoon
Korea Institute of Nuclear Non-proliferation and Control
P.O.Box 114, Yuseong, Daejeon, Korea 305-600

1. Introduction

As the potential threat to nuclear facilities have increased, methods have been developed to evaluate such possible risks. Recently, the NNSA, the internal organization of the U.S DOE, has established the PR&PP group for the Generation-IV project, and are developing evaluation methodology on Proliferation Resistance (PR) and Physical Protection (PP) for this future nuclear energy system. Unlike the PR study[1,2,3], which began in the early 1970s, the study on the PP initiated on a large scale recently. The purpose of the Gen-IV PR&PP group is to develop quantitative methodologies. In order to express the PR & PP value quantitatively, the evaluation measures should be determined beforehand. The Gen-IV PR&PP group suggested six measures for PR and three measures for PP[2]. The six measures for PR had been verified as they were developed through a series of studies beginning in the 1970s. In comparison with the PR measures, PP measures suggested by the group need to be reviewed. In this work, we investigated the PP measures and developed more realistic measures for PP evaluation.

2. PP measures for Gen-IV

The Gen-IV PR&PP group suggested three measures for PP evaluation: Probability of Adversary Success, Consequences and Physical Protection Resources. Detailed explanations for these measures are as follows[2] :

Probability of Adversary Success – The probability that an adversary will successfully complete a pathway and generate a consequence.

Consequences – The effects resulting from the successful completion of the adversary's intended action described by a pathway, including the effects of mitigation measures.

Physical Protection Resources – The staffing, capabilities, and costs required to provide PP, such as background screening, detection, interruption, and neutralization, and the sensitivity of these resources to changes in the threat sophistication and capability

3. Development of PP measures

3.1 Analyzing PP measures

The effectiveness of the PPS is measured in terms of the risk of a successful attack. It is composed of the probability of an adversary attack(Pa), the probability of successful an adversary attack(Ps) and the consequences of an attack(C)[4,5]. These factors are very similar to the measures developed by the Gen-IV PR&PP group, but excluding the probability of adversary attack. The calculation of the probability of an attack has historically been extremely difficult. Instead of Pa, a measure on physical protection resources is selected in the Gen-IV PR&PP study. There are so many factors involved in evaluating PP that the three measures suggested by the Gen-IV PR&PP group are not enough to express them. They need to be separated in detail. The parameter that may influence on PP include the primary function of the physical protection system, the results from an attack, the legal and institutional framework, material types that can be used or targeted and other physical protection related resources. There are three primary functions of the physical protection system: detection, delay and response. Detection is an activity that senses the unauthorized action and creates an alarm. Details of facilities layout and specific functions are required for analysis. Delay is a process to obstruct an adversary's progress. This is usually accomplished by barriers and also by response forces. The delaying effectiveness can be measured by the time to bypass the delay elements. The response is the action taken by the protective force to prevent an adversary's success. It is composed of two independent functions: interruption and neutralization. Consequences from an attack can be separated as human loss, economic loss, contamination of the region and indirect effects such as the loss of public confidence. It is not easy to evaluate the consequences quantitatively, as too many factors are involved. Whether the country or the facility has a proper legal and institutional framework for PP is an important factor, but the degree of it is also difficult to evaluate. Material type is another major parameter as consequence is heavily dependent upon the quantity and type of material involved in attack. The effect of material type can be changed according to the attack mode. The capability of staff, MC&A(Material Counting & Accountancy) activity and background checks on staff are typical example of physical protection related resources. They should also be considered.

3.2 Newly developed measures for PP

Five measures for evaluating PP were developed after collecting, reviewing and evaluating all the factors that may affect PP. They are different from those developed by the Gen-IV PR&PP group and reflected all the factors. Detailed explanation of these measures includes:

Probability of Adversary Interruption – The probability that the attack will be interrupted by a response force. It consists of detection and delay function.

Probability of Adversary Neutralization – The probability that the adversary will be neutralized by facility's safeguards and offside response force team

Consequences – The effect resulting from an attack. It is composed of direct and indirect results.

Fissile Material Type – A categorization of material based on the degree to which its characteristics affect its utility for use in an attack or its attractiveness for being a target.

Effectiveness of Physical Protection Resources – The degree of how much physical protection resources are effective. Physical protection resources include background checks on staff, MC&A activity and the PP staff's capability and education. Unlike the measure defined by the Gen-IV PR&PP group, it does not contain the activity related to detection, interruption and neutralization.

In order to utilize the measure developed from this study, typical attributes should be provided. Table 1 show the attribute derived from each measure. Based on that, PP can be evaluated quantitatively. Currently, many studies have been performed to develop the evaluation methodology by which the quantitative value for each measure can be calculated.

Table 1. List of sub-measure

Measure	Attribute
Probability of Adversary Interruption (PI)	• Extrinsic barrier • Intrinsic barrier • Detection ability
Probability of Adversary Neutralization(PN)	• Capability of response force team (Number/weapons) • Response force time
Consequences(C)	• Direct loss(death toll, economic, contamination area, etc) • Indirect loss(public confidence)
Fissile Material Type(MT)	• Radioactivity levels • Criticality hazards
Effectiveness of Physical Protection Resources(EPP)	• MC&A • Background check • Education

4. Conclusion

The measure that can be used as a means of evaluating PP had been developed. Five measures were developed through the process of collecting and reviewing all the factors concerned. Each measure can be evaluated both quantitatively and qualitatively. These are different from those developed from the Gen-IV PR&PP study. The probability of an adversary's success is divided into two parts, the probability of adversary interruption and probability of an adversary's neutralization. Two other measures, consequences and physical protection resources, have been changed. It is expected that a more realistic evaluation can be performed using these measures.

Further study for developing methodology to calculate these measures quantitatively is needed.

Acknowledgement

This work has been carried out under the Nuclear Research and Development program supported by MOST

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