Evaluation of Effectiveness of Performance-based Physical Protection System

S. Y. Kim*, H. H. Lee, E. H. Kwon, H. D. Kim
Korea Atomic Energy Research Institute
Daedeok-daero 989-111, Yuseong-gu, Daejeon 305-353, Republic of Korea
**Corresponding author: sykim@kaeri.re.kr*

1. Introduction

The September 11 attacks in the US prompted the international community, including the International Atomic Energy Agency (IAEA), to recognize the importance of strengthening the physical defenses of the nuclear facilities in their own territories. Against this backdrop, in a bid to provide recommendations and guidance for member countries in the creation and implementation of physical protection programs, the IAEA published its Nuclear Security Series in 2006 and revised INFCIRC/225/Rev.4 in 2011 to issue INFCIRC/ 225/Rev.5 (Rev.5) as the IAEA's comprehensive recommendation concerning the physical protection of nuclear material and nuclear facilities [1]. The revised recommendation stresses on a performance-based approach, in addition to prescriptive-based guidelines serving as the basis for the design, implementation, and assessment of an existing physical protection system (PPS). This paper aims to explain the performance-based PPS and discuss how it will move forward.

2. Risk Assessment Analysis

A performance-based approach is referenced in quality assurance in sustaining the physical protection regime in Rev.5, and it affects risk management in risk based physical protection system and measures. This paper primarily examines risk assessment. Risk management is a systemic approach to analyze, evaluate, and control a variety of risks in order to minimize them. It defines where a performance-based PPS affects a risk-based PPS from the perspective of the security risk and potential liability for damage.

Risk (R) generally consists of the probability of a certain phenomenon arising (P) and the consequences of that phenomenon (C). It is represented by formula (1) below.

$$R = P * C \quad (1)$$

The security risk (R) taken into consideration in the implementation of a PPS is influenced by the probability of an adversary completing an attack, or P, where P is composed of the probability of the adversary launching an attack and the probability of the attack succeeding, as described in formula (2) below.

$$P = P_A * P_S \quad (2)$$

If an attack from an adversary occurs, either the PPS will function efficiently and defeat the adversary, or it will fail in its defense, allowing the adversary to succeed. Successfully defending against an adversary can be expressed as the probability of system effectiveness (P_E), while the success of the adversary's attack can be expressed as P_S. Hence, the following formula (3) holds.

$$P_E + P_S = 1 \quad (3)$$

Taking advantage of formulas (1), (2), and (3), formula (4) can be used to represent the security risk.

$$R = P_A * (1-P_E) * C \quad (4)$$

According to formula (4), the following methods can be used to mitigate the security risk: reduce the probability of an adversary launching an attack (P_A), enhance the probability of PPS system effectiveness (P_E), and decrease the severity of the consequences of a successful attack (C). Among these, the probability of PPS system effectiveness (P_E) can be measured quantitatively using the performance-based PPS implementation approach. Thus, the performance-based PPS described in this paper addresses how to measure and improve the probability of system effectiveness (P_E).

2.1. Security System Effectiveness

P_E indicates the probability of the PPS functioning effectively to prevent an adversary from achieving its objectives. This probability is determined by two factors: the probability of interruption, or the probability of the response force being deployed in a timely manner to the battlefield to combat the adversary; and the probability of neutralization, or the probability predicting the outcome of the battle between the adversary and the response force. This can be described in the following formula (5).

$$P_E = P_I * P_N \quad (5)$$

2.2 Probability of Interruption

The probability of interruption (P_I) assesses the length of time until a response force is deployed when an adversarial attack occurs. This assessment requires the prediction of the length of time for the adversary to reach the target site. To that end, it is necessary to physically reconstruct the facility to create a model, and then devise an adversary sequence diagram, including setting the course elements, the probability of detection by sensors arranged in the physical zones (P_D), and delay time. The value derived from the adversary sequence diagram allows us to determine the worst route.

Sandia National Laboratories (SNL) has developed the tool Estimate of Adversary Sequence Interruption (EASI) to estimate the probability of interruption for a single route. The probability of interruption is based on the probability of elements of the worst route being detected by sensors and the delay time, as mentioned above, along with the time for the system to assess the alert and the time taken by the response force to prepare and travel to the site.

Estimate of Adversary Sequence Interruption	Probability of Guard Communication		Response Force Time (in Seconds) Mean	Standard Deviation
	0.95		300	90

Task	Description	P(Detection)	Location	Delays (in Seconds): Mean:	Standard Deviation
1	Cut Fence	0	B	10	3
2	Run to Building	0	B	12	3.6
3	Open Door	0.9	B	90	27
4	Run to Vital Area	0	B	10	3
5	Open Door	0.9	B	90	27
6	Sabotage Target	0	B	120	36
7					
8					
9					
10					
11					
12					

Probability of Interruption:	0.47604073

Fig. 1. Input and output of EASI.

2.3 Probability of Neutralization

The probability of neutralization (P_N) assesses whether the adversary or response force is most likely to win a confrontation. For this purpose, Lanchester's laws can be applied to consider the size of the response force versus the size of the adversary. Under the assumption that the battle capacities and circumstances of both troops are identical, Lanchester's laws forecast an outcome based solely on the number of troops. The size of the adversary is based on what is defined in the Design Basis Threat (DBT).

3. Result and Review

If P_E calculated based on P_I and P_N meets the standard imposed by the regulatory institution, the PPS may proceed to the final PPS design stage, but if not, redesign is required. During that process, the designer must review the consequences of changes in the sensors or obstacles constituting P_I, as well as how the size or location of the response force influences P_N.

4. Expected Effectiveness

For an existing PPS, it has been difficult to build systems in an economically efficient manner because the protection details are defined by the regulatory institution, and the business operator must simply implement these requirements. By contrast, for a performance-based PPS, the regulatory institution sets performance requirements, and the business operator designs the PPS to meet these requirements and proves to the regulator that the PPS is consistent with these requirements. Therefore, business operators have grounds for optimizing the structure of their facility, including the installation of sensors and obstacles and the size and location of the response force under the given conditions, while meeting the standard criteria for performance.

The DBT under protection by a PPS is to be defined by the government. In the case of Korea, for example, it is based on the circumstances at home or abroad. A performance-based PPS is capable of determining whether the PPS is sufficient to fully deal with the changing DBT, and the elements that will be most efficient if updating is necessary.

5. Conclusions

This paper elaborated on the status of the performance-based PPS, as a way to achieve the quantitative performance criteria set forth in Rev.5, in the area of risk assessment and the definition and constituents of consequence. A performance-based PPS is internationally significant in that it can validate the feasibility of the physical defense of nuclear plants in operation at home and for export as recommended by the IAEA. On the domestic front, it enables a business operator to make efficient judgments from an economic perspective based on quantitative objectives while designing, implementing, and modifying their PPS.

Despite these advantages, however, the performance-based PPS has yet to be sufficiently reviewed and introduced in Korea. The need to analyze situations such as those in which an adversary infiltrates via multiple routes or is aided by an internal threat, has yet to be taken into consideration when estimating the probability of interruption. In addition, while the probability of neutralization and the probability of interruption are both important, and therefore should be duly reviewed, insufficient efforts have been made to quantify and assess the elements related to the response force and battle.

REFERENCES

[1] International Atomic Energy Agency, "Nuclear Security Recommendation on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Rev.5)", Nuclear Security Series, No.13, 2011.