Physical protection evaluation methodology program development and application

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1. Introduction

For effective physical protection of nuclear facilities, it is important to reflect the physical protection concept from the design and authorization stage. Through the design optimization process of physical protection system, the most balanced one in terms of effectiveness and efficiency should be chosen among several design options. Also the iterative improvement process including vulnerability assessment and reflection of countermeasure is an important step in the system design. Therefore it is essential to develop a reliable physical protection evaluation methodology for applying physical protection concept to the design stage. The methodology can be used to assess weak points and improve performance not only for the design stage but also for nuclear facilities in operation.

Analyzing physical protection property of nuclear facilities is not a trivial work since there are many interconnected factors affecting overall performance. Therefore several international projects have been organized to develop a systematic physical protection evaluation methodology. INPRO (The International Project on Innovative Nuclear Reactors and Fuel Cycles) [1] and GIF PRPP (Generation IV International Forum Proliferation Resistance and Physical Protection) methodology [2] are among the most well-known evaluation methodologies. INPRO adopts a checklist type of questionnaire and has a strong point in analyzing overall characteristic of facilities in a qualitative way. On the other hand, GIF PRPP methodology evaluates quantitative physical protection effectiveness through the performance-based analysis. To utilize benefits from both approaches, COMPRE PP (Comprehensive Methodology for PR&PP Evaluation Physical Protection) [3] has been developed. It is composed of 5 high-level measures and aiming at systematic physical protection analysis. Also, COMPRE program has been developed to help general users apply COMPRE methodology to nuclear facilities. In this work, COMPRE program development and a case study of the hypothetical nuclear facility are presented.

2. COMPRE program development

To establish a user-friendly platform of COMPRE application, COMPRE program is developed. It is composed of two top-level modes which are administrator and evaluation modes. In the administrator mode, a database of evaluation measures is generated. As shown in Fig. 1, an administrator mode consists of several sub-windows.

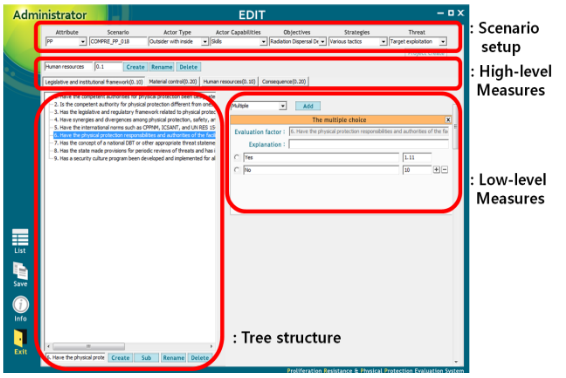

Fig. 1. Administrator mode screen

In the high-level measure window, high-level measures of COMPRE PP methodology are presented. In the tree structure and low-level measure window, low-level questionnaire assigned to each high-level measure is shown in the tree structure. The evaluation of specific scenarios or facilities can be performed in the evaluation mode once the questionnaire database is established. After all measures are answered as shown in Fig. 2, quantitative results calculated by summing weighted scores are presented in the form of lists or diagrams.

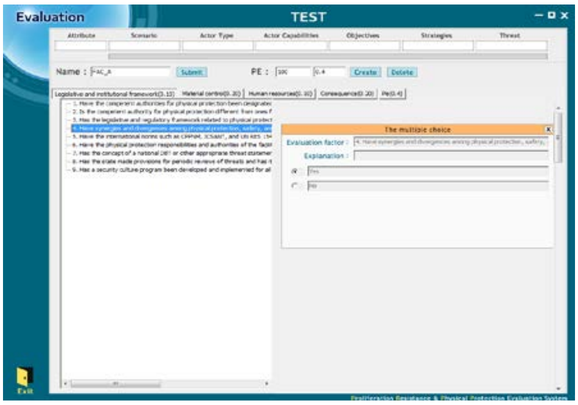

Fig. 2. Evaluation mode screen

3. ESFR case study

To obtain experience and find possible rooms for further improvement, COMPRE PP methodology is applied to hypothetical ESFR (Example Sodium Fast Reactor) developed by GIF PRPP group [4]. Note that some unavailable information is assumed for this case study.

(1) LI (Legislative and Institutional framework)

Questionnaire		Ans	score
1	Have the competent authorities for physical protection been designated and empowered, as well as their responsibilities defined?	Yes	0.1
2	Is the competent authority for physical protection different from ones for safeguards?	Yes	0.1
3	Has the legislative and regulatory framework related to physical protection been developed (or is it under development)?	Yes	0.1
4	Have synergies and divergences among physical protection, safety, and safeguards been addressed?	No	0.9
5	Have the international norms such as CPPNM, ICSANT, and UN RES 1540 been ratified and have their provisions been reflected in the regulatory frameworks?	Yes	0.1
6	Have the physical protection responsibilities and authorities of the facility operator been clearly defined?	Yes	0.1
7	Has the concept of a national DBT or other appropriate threat statements been used to establish the PP systems?	Yes	0.1
8	Has the state made provisions for periodic reviews of threats and has it developed a DBT?	Yes	0.1
9	Has a security culture program been developed and implemented for all organizations?	Yes	0.1

(2) MC (Material Control)

Questionnaire		Ans	score
Categories of NM	Enrichment (U-235, U-233, Pu)	<50%, ≥20%	0.4
NMAC System	MBA (Material Balance Area) & KMP (Key Measurement Points)	Established	0.1
	Records Management	Accounting records and operation records	0.1
	PIT (Physical Inventory Taking)	Every three month	0.5
	Nuclear Material Control	One control measure	0.5
	Nuclear Material Movement	Documentation and verification	0.1
	Assessment	Assessment program only	0.5

(3) PPSE (Physical Protection System Effectiveness)

PPSE represents how effective a physical protection system is against a specific threat scenario. Therefore PPSE is different for each scenario and defined as follows. [5]

$$PPSE = P_I \times P_N$$

PPSE = Physical Protection System Effectiveness
P_I = Probability of Interruption
P_N = Probability of Neutralization

In this work, P_I (=0.95) and P_N (=0.86) are evaluated from TESS (Tool for Evaluating Security System) program applied to ESFR main control room sabotage scenario as a demonstration example.

(4) HR (Human Resources)

Questionnaire		Ans	score
Nuclear Security Culture	Existence of documents related to the nuclear security culture	Regulation and guidance documents	Medium (0.2)
	Frequency of employee training	2/year	Medium (0.2)
	Frequency of security exercises	1/year	High (0.5)
	Frequency of nuclear security self-assessments	None	Critical (0.9)
Effectiveness of Resources	Total number of employees (including contractors)	500~1500	Medium (0.2)
	Percentage of employees who can access vital areas	<1% or ≥5%	High (0.5)
	Frequency of background checks (number)	None	Critical (0.9)

(5) C (Consequences)

To obtain reliable consequence values for each scenario, a sophisticated radiological impact assessment for threat scenarios is necessary. In this work, it is simply assumed that only small amount of nuclear material (<= 50 mSv/1 week on site) is released from the reactor for a demonstration purpose.

(6) Overall vulnerability result

Overall vulnerability result is obtained from the additive summation of scores multiplied by the weight assigned to each measure.

Measures	Before weighted	After weighted
LI (Legislative and Institutional framework : weight = 0.1)	24	2.4
MC (Material Control : weight = 0.2)	39	7.8
PPSE (Physical Protection System Effectiveness : weight = 0.4)	19	7.6
HR (Human Resources : weight = 0.1)	49	4.9
C (Consequences : weight = 0.2)	10	2
Overall		24.7

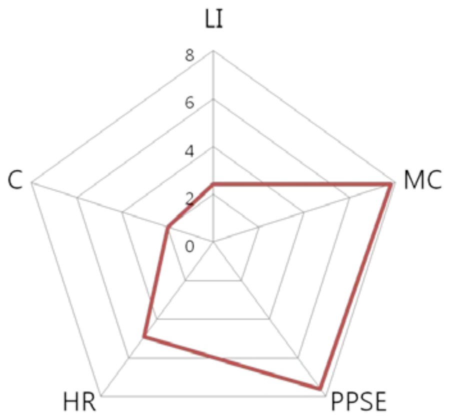

Fig. 3. Vulnerability spider diagram

In Fig. 3 , vulnerability score for each measure is shown as a spider diagram. As shown in the figure, PPSE and MC are relatively vulnerable areas to malicious threats. The high vulnerability value of PPSE is due to relatively low neutralization probability (=0.86) and the vulnerability of MC is originated from the ineffectiveness of NMAC system. Although the analysis of this work is an example only for the demonstration purpose, this kind of analysis can be useful to find rooms for improvement when it is applied to the evaluation of real nuclear facilities in the design or operation stage.

4. Discussion and future work

The development of COMPRE program and a case study for hypothetic facility is presented in this work. The case study shows that COMPRE PP methodology can be a useful tool to assess the overall physical protection performance of nuclear facilities.

To obtain meaningful results from COMPRE PP methodology, detailed information and comprehensive analysis are required. Especially, it is not trivial to calculate reliable values for PPSE (Physical Protection System Effectiveness) and C (Consequence), while it is relatively straightforward to evaluate LI (Legislative and Institutional framework), MC (Material Control) and HR (Human Resources). To obtain a reliable PPSE value, comprehensive information about physical protection system, vital area analysis and realistic threat scenario assessment are required. Like PPSE measure, consequence measure also has a strong dependence on the specification of threat scenarios and target characteristic. Therefore a capability of thorough threat analysis and radiological impact assessment is essential to evaluate the consequence measure.

Last but not least, a verification process of weight assigned to each measure is also important. To do this, expert elicitation with AHP (Analytic Hierarchy process) is planned as a future work.

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