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Development of Vital Area Identification Method for Korean Nuclear Power Plant Design

Woo Sik Jung
Integrated Safety Assessment Division, Korea Atomic Energy Research Institute
woosjung@kaeri.re.kr

1. Introduction

Since the attack on the World Trade Center on September 11, 2001, US Nuclear Regulatory Commission (NRC) has enforced electric power utilities to evaluate the level of physical security when designing a new nuclear power plant. In addition, International Atomic Energy Agency (IAEA) established security-related department and has been strengthening security measures against potential sabotage. Accordingly, there has been growing worldwide interest in developing Vital Area Identification (VAI) method as one of the possible measures against sabotage. The United States is most actively taking advantage of Vital Areas by determining and protecting them.

2. Development of Vital Area Identification Method

The definition of Vital Area in IAEA document INFCIRC/225/Rev.5[1] is “an area inside a protected area containing equipment, systems or devices, or nuclear material, the sabotage of which could directly or indirectly lead to unacceptable radiological consequences (URC).” For the VAI of IAEA member states, IAEA developed VAI procedure [2] and SNLs adopted it as an important technical reference of the SAND2008-5644 report [3].

VAI is a procedure to determine a set of rooms that should be protected against sabotage in order to suppress or avoid URC such as core damage. There is infinite number of Target Sets or Prevention Sets in a nuclear power plant. Target Sets are minimal sets of room destructions that can cause URC and Prevention Sets are minimal sets of room protections that suppress URC. The Target Sets and Prevention Sets are calculated from the Sabotage Fault Tree. The Sabotage Fault Tree can be manually or automatically obtained by replacing component failures (basic events) in a PSA model with room failures [4].

In the project sponsored by Korean government (MEST), “Development of a Vital Area Identification Technology in the Nuclear Facilities (2007.3-2012.2) [4]”, PSA-based VAI method has been developed.

(1) In the first phase research from 2007 to 2009, a new VAI method that reuses Fire/Flooding PSAs was developed. The VAI method is based on Jung's Single Top And Run (JSTAR) method [5, 6] that combines various Fire/Flooding PSA models into a single fault tree.
(2) In the second phase research from 2010 to 2011, the PSA-based VAI method was implemented into VAI software VIPEX (Vital area Identification Package Expert).
(3) Finally, VAI procedure that reuses Fire/Flooding PSA models was developed [7] and it was applied to the VAI of Ulchin 3/4 nuclear power plant [4]. The VAI procedure consists of the five following steps: (a) collect internal/fire/flooding PSA models, (b) combine PSA models by JSTAR method into a single fault tree that has a top event of URC such as core damage, (c) convert combined PSA model into a Sabotage Fault Tree, (d) calculate Target Sets and Prevention Sets that consist of room failures and room protections, respectively, and (e) select the most economical Prevention Set and protect the rooms in the selected Prevention Set as Vital Areas.

3. Application

3.1 Hypothetical Plant

In this Section, VAI method is explained with a hypothetical facility of High Activity Waste Storage Facility (HAWSF) [8] in Fig. 1. It is a tutorial model of VAI workshop directed by Sandia National Laboratories.

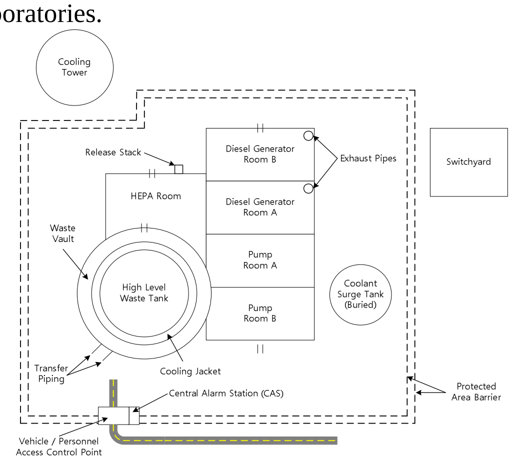

Fig. 1. High Activity Waste Storage Facility (HAWSF) [8]

Fault tree for the hypothetical facility system in Fig. 1 is developed first, and each component failure in a fault tree is replaced with a room failure(s) where the component is located. The replacement is automatically performed by VIPEX according to the mapping information in Table I.

VIPEX generates a sabotage fault tree by combining a given fault tree and mapping information from component failures to room failures in Table I. Then, FTREX solves the sabotage fault tree and generates Target Sets and Prevention Sets as listed in Table II. One of most competitive Prevention Sets is selected and the rooms in the selected Prevention Set are protected against sabotage attack.

Table I. Mapping from room failures to basic events

Room failures		Events
Single room failures	CST	A-SUCT-FLOW, B-SUCT-FLOW, A-SUCT-FLOW-D, B-SUCT-FLOW-D
	DA	DG-A-EQUIP, DG-A-FUEL, DG-A-START, SWG-A-FAIL (a)
	DB	DG-B-EQUIP, DG-B-FUEL, DG-B-START, SWG-B-FAIL (b)
	HR	HEPA-A-LEAK, HEPA-B-LEAK, HEPA-A-PLUG, HEPA-B-PLUG, VLV-A-MECH, VLV-B-MECH
	PA	A-SAB-LOCAL, A-DIS-FLOW, A-SAB-LOCAL-D (c)
	PB	B-SAB-LOCAL, B-DIS-FLOW, B-SAB-LOCAL-D (d)
	SW	Not applicable since Switchyard is out of protected area
	TV	BDB-BREAK
Fire transfer Room failures	DA_DB(e)	8 events from (a) and (b)
	DB_DA(e)	8 events from (a) and (b)
	PA_PB(e)	6 events from (c) and (d)
	PB_PA(e)	6 events from (c) and (d)

(e) X_Y Fire transfer from X to Y

Table II. Target Sets and Prevention Sets

	Target Sets	Prevention Sets
Ignore fire transfer(a)	TV CST PA * PB DA * PB DA * DB DB * PA	/TV * /CST * /DA * /PA /TV * /CST * /DB * /PB
Accept fire transfer(b)	TV CST DA DB PA PB	/TV * /CST * /DA * /DB * /PA * /PB

(a) Ignore fire transfer room to room (DA_DB, DB_DA, PA_PB, and PB_PA)
(b) Include fire transfer room to room (DA_DB, DB_DA, PA_PB, and PB_PA)

3.2 Ulchin 3/4 Nuclear Power Plant

VAI for Ulchin 3/4 nuclear power plant was performed in order to show the effectiveness of the developed method [4]. The results are summarized in Table III.

Table III. VAI results of Ulchin 3/4 NPP

	Sabotage model	PSA model
Gates	5,515	4,896
Events	2,386	2,295
Mapped events	272	
Mapped rooms	91	
Target Sets	932 (a)	
Prevention Sets	50 (b)	

(a) Length = 1 to 5, (b) Length = 29 to 45

4. Conclusions

In this research and development study [4], VAI method, procedure, and software were developed. The results are

(1) Development of the JSTAR method that integrates fire/flooding PSA results into a single fault tree,
(2) Development of the five-step VAI procedure that reuses fire/flooding PSA models by employing JSTAR method,
(3) Implementation of the five-step VAI procedure into VAI software VIPEX,
(4) VAI for the Ulchin 3/4 nuclear power plant by reusing its fire/flooding PSA results, and
(5) Completion of VAI procedure document for the protection design of operating/new/export nuclear power plants.

5. Recommendations

IAEA enforces the VAI recommendations in the INFCIRC/225/Rev.5 and the United States NRC also enforces the similar VAI requirements in 10 CFR 73.55. Thus, in order to comply with the INFCIRC/225/Rev.5, Korea nuclear licensee should perform the VAI for the operating and new nuclear power plants.

Since the design of the Korean nuclear power plant that is under construction in the United Arab Emirates (UAE) should comply with U.S. NRC requirements, (1) the vital areas should be identified in the design stage of the nuclear power plant and (2) the identified vital areas should be secured by implementing appropriate protection measures. Thus, the method and software that were developed in this study can play an important role in designing more secured nuclear power plants that might be additionally exported in the future.

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