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Target Identification against Radiological Terrorism Sabotage on a Spent Fuel Pool System

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1. Introduction

Nowadays, we pay attention to a matter of safety and security relative to complex risky facilities and infrastructures (e.g., nuclear facilities, gas pipelines and tanks) as a hot issue to be tackled by a variety of stakeholders such as politicians, scientists, utilities, NGOs and so forth. In particular, since the 9/11 terrorism attacks, **a radiological sabotage** becomes one of interesting research topics in the engineering field. According to 10 CFR 73.2, a radiological sabotage could endanger the public health and safety by exposure to radiation.

Terrorism sabotage can be classified by three types as follows: 1) industrial sabotage, 2) toxicological sabotage, and 3) radiological sabotage. By them we mean any deliberate activities directed against a facility that could endanger the industry by capacity loss, the public by exposure to chemical toxic, and by exposure to radioactive sources, respectively.

With regard to a nuclear power plant (NPP), the radiological sabotage requires terrorists to damage to the reactor core in a containment or/and **irradiated fuel bundles** in the spent fuel pool (SFP) in a fuel handling building at the site. In Figure 1, an arrangement of these vital systems is given. SFPs have been the major concerns among scientists since they are more vulnerable to sabotage attacks than the reactor core. The reasons for more vulnerability are that 1) a SFP is housed in far less robust structures than the containment, and 2) a SFP contains much more radiation than a reactor core [Zhang].

A primary objective of this study is to identify the sabotage targets associated with a spent nuclear fuel pool system that stores irradiated fuel bundles in the SFP at the site of a NPP.

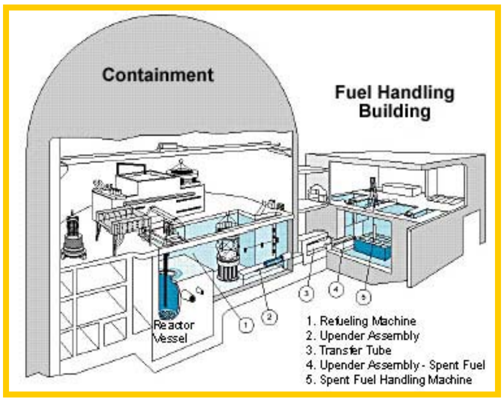

Figure 1. A 3D View of the SFP [Union of Concerned Scientists]

2. Methods and Data

Among various approaches to assessment of the sabotage risk [Kim *et al*. 2007], a **fault tree analysis** (FTA) approach is used for identifying sabotage targets and cost-effectively protecting them vulnerable to sabotage attacks.

2.1 Methods

As for terrorism target identification in a complex system, a FTA approach has been formulated in SNL to deal with vital area identification (VAI) problems [Hockert and Beck 2005]. By **vital area** we mean any area inside a protected area containing targets to be protected against sabotage attacks that could lead to unacceptable radiological consequences [IAEA 1999].

A VAI procedure based on three steps is applied: At **step 1,** minimal cutsets (MCSs) are generated. Firstly, a top-event (e.g., core damage, release of radioactive material) is defined and then a FT model is developed. At **step 2**, MCSs are transformed into minimal pathsets (MPSs) by means of two Boolean operations (i.e., replacement and complement). At **step 3**, top event prevention sets (TEPSs) are obtained. In order for MPSs to be formed as TEPSs, a conversion matrix from the basic event (BE) failure to the room failures needs to be constructed using plant-specific drawings.

Finally, vital areas consist of the elements of TEPSs. For the calculation, the software tool named as VIP [Jung 2005] is used.

2.2 Data

In reality, a wet SFP at the site of a NPP is utilized as temporary storage of a limited number of irradiated fuel bundles in a dense density, open frame configuration, even though it is designed in a low density configuration [Public Citizen 2006]. A sabotage attack to the SFP can cause environmental release of radioactive sources such as Cs 137, which has 30-year half-life and is relatively volatile so as to be a potent land contaminant. For instance, it is estimated that the long-term release **impact of Cs 137** inventory in the SFP exceeds 8~17 times compared to the radiological impact of the April 1986 Chernobyl accident [Zhang].

In the present work, a SFP system has been chosen to identify sabotage targets. The main reason for it is that the fission product Cs 137 is potentially released from the SFP.

In Figure 2, a configuration of the system under consideration is schematically shown for the NPP, especially the type of a pressurized water reactor. The SFP cooling system of Ulchin 3&4 NPPs is modeled along with specific data available in the literature [KEPCO 1998].

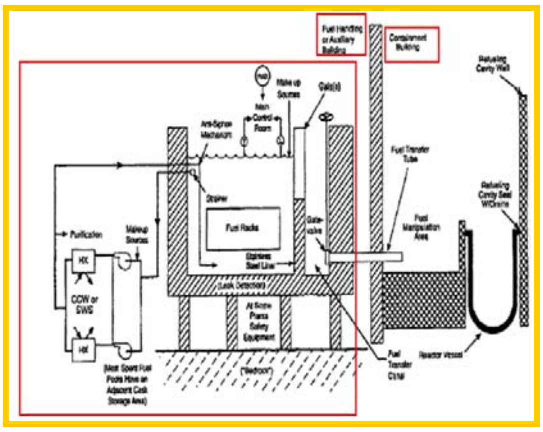

Figure 2. Layout of SFP System for a PWR [NRC 1997]

3. Results

In this section, results obtained from the sabotage target identification using a TEPS method were introduced.

A sabotage FT model for the SFP system was constructed. In Figure 3, FT diagrams are given. Here, the top event is defined as a loss of pool water induced by a sabotage attack. The FT model contains three scenarios as follows: the loss of cooling (Scenario 1), the drainage of SFP coolant inventory (Scenario 2), and the puncturing the pool and causing drainage (Scenario 3) [Zhang].

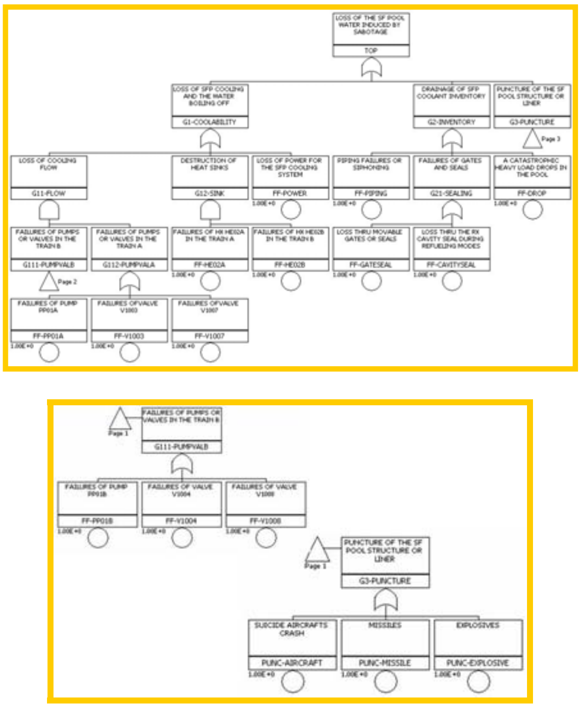

Figure 3. A Sabotage Fault Tree Diagram

As described in Eq. (1), MCSs are identified.

MCS = (1)
{R-CONT, R-POOL, R-POWER,
(R-PPA)*(R-PPB), (R-HEA)*(R-HEB)}

Concerning the security, a defense-in-depth (DID) is viewed as a sort of defense strategies using similar and/or diverse overlapping provisions such that an adversary has to neutralize multiple defensive barriers to meet her/his goals. The DID concept can be applied to the design of physical protection systems [IAEA 1999].

For two levels of DID (level 1 and the level 2), the TEPSs are expressed as Eqs. (2) and (3), respectively.

TEPS = (2)
{(R-CONT)*(R-HEB)*(R-POOL)*(R-POWER)*(R-PPA),
(R-CONT)*(R-HEA)*(R-POOL)*(R-POWER)*(R-PPA),
(R-CONT)*(R-HEB)*(R-POOL)*(R-POWER)*(R-PPB),
(R-CONT)*(R-HEA)*(R-POOL)*(R-POWER)*(R-PPB)}

TEPS = (3)
{(R-CONT)*(R-HEA)*(R-HEB)*(R-POOL)
***(R-POWER)*(R-PPA)*(R-PPB)}**

At the security level 1, the following rooms are identified as **vital areas**: four locations composed by 5 rooms such as (Containment, Pool, Power and a combination between heat exchanger room A/B and pump room A/B).

At the security level 2 that remains much deeper than at the level 1, vital area is just one location that comprises 7 rooms such as (Containment, Pool, Power, heat exchanger room A, heat exchanger room B, pump room A, and pump room B).

It is worthy of note that the deeper the security level is held, the more rooms we have to protect against sabotage. That is, more resources are allocated to the case of deeper security. It should be addressed that real room identifier is available in the literature (See the Chapter 3 in [KEPCO 1998]).

4. Conclusive Remarks

In the present work, a FT analysis approach to sabotage risk assessment was applied for the identification of potential sabotage targets. As for the handling of PSA-models, irradiated fuel bundles as a surrogate for radiological sabotage were incorporated into the sabotage FT developed. Concerning the handling of BE-room mapping, generic room identifier was used instead of real room identifier for the sake of the confidential matter..

For the near future work, both the core damage and the spent fuel bundles can be modeled as a surrogate for radiological sabotage.

Acknowledgement

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