A Study on Potential Risk of Nuclear System associated with Nuclear Hydrogen Production

Seok-Jung HAN & Joon-Eon YANG
Korea Atomic Energy Research Institute, P.O. Box 105, Yuseong, Daejeon, South Korea,
hanseok@kaeri.re.kr

1. Introduction

In many countries, the several types of nuclear hydrogen production facilities are under developments now. These facilities have a safety issue that could arise from interfacing events between nuclear and non-nuclear facilities (Fig.1). In the early development stage, an essential part of this safety issue is to identify the risk of the nuclear facility from potential threats of the hydrogen production facility. As a preliminary work, this study focuses on an establishment of an approach to the identification of their potential risk factors by using a PSA method.

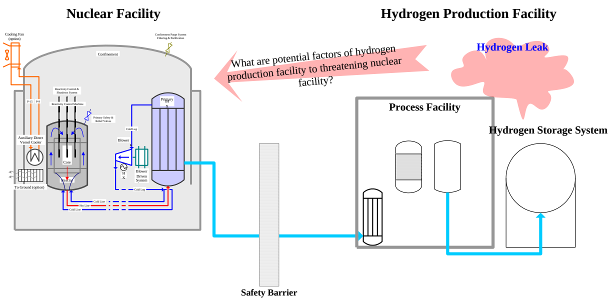

Fig.1. A concept of the risk of nuclear facility from potential threats of hydrogen production facility

2. Assessment Procedure

Main considerations of this study to be applied in the conceptual design stage are to identify potential threat factors of hydrogen production facility to nuclear facility, to assess their effect on nuclear facility, and to propose an effective implementation procedure.

This study established a two-step procedure for this assessment except the consequence analysis (Fig.2):

- Step 1: Identification of potential threat factors
- Step 2: Accident progression assessment from the identified factors

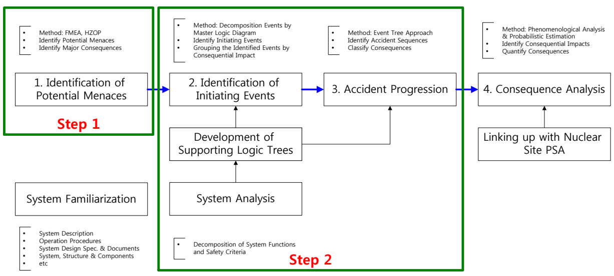

Fig.2. A proposed assessment procedure

Main objectives of Step 1 are to identify the potential threat factors and to classify their consequential impacts on the nuclear facility. For this purpose, Step 1 adopted a combined method of subjective (Engineering judgments) and systematic (FMEA) approaches.

Step 2 used a nominal PSA approach for qualitative and quantitative risk assessment from the identified threat factors. In the Step 2, master logic diagram (MLD) for identifying the initiating events and event tree modeling for accident progression were used as the major quantification approach.

3. Feasibility Study

2.1 Identification of Potential Threat Factors (Step 1)

According to the types and characteristics of each factor due to abnormal conditions of the hydrogen production facility, types of impact on the nuclear facility were classified as Table 1.

Table 1. Types of impacts on the nuclear facility due to abnormal conditions of the hydrogen production facility

Impact type	Feature		Final effect			Duration
General abnormal	Requiring reactor trip		Reactor trip			Short term
	Requiring isolation from hydrogen production facility		Reactor trip	Isolation		Short term
Malfunction in interface (degradation, failure etc)	Intact physical boundary of nuclear system		Reactor trip			Short term
	Trouble occurs in interface system	Physical effect	Reactor trip	Isolation		Short term
		Chemical effect	Reactor trip	Isolation		Long term
Specific Effect	Effect by physical attack (Ex. explosion pressure or impact of explosion debris)		Reactor trip	Isolation	Special features	Short term
	Effect by chemical attack (Ex. effect of chemical toxic materials)		Reactor trip	Isolation	Special features	Long term

Among these types of disturbances on the nuclear facility according to its responses, a primary impact was identified as the specific impact due to hydrogen leak. This study identified that a large scale leak of hydrogen gas from the hydrogen storage system and its explosion could become a major potential threat to the nuclear facility. Impacts on nuclear facility due to hydrogen explosion were classified as an effect of shock wave and an impact of explosion debris. For risk assessment, their impact on nuclear facility should be assessed.

2.2 Accident Progression Analysis from Identified Factors (Step 2)

A major source of a large scale hydrogen leak was estimated as its hydrogen storage system not the hydrogen production facility itself. The risk assessment of identified threat factor, (i.e., a large scale hydrogen leak) focused on the hydrogen storage system and its effect on the nuclear facility.

- Hydrogen Storage System (Example)

This study has prepared a conceptual diagram of the hydrogen storage system to use it in a feasibility study (Fig.3)[1]. As considering its essential function, primary considering factors among its essential design specifications were the size and the storage capacity of hydrogen gas. Secondary factors were storage conditions and their specifications on design and operation. The other things consist of engineered features for its operation and its safety [1].

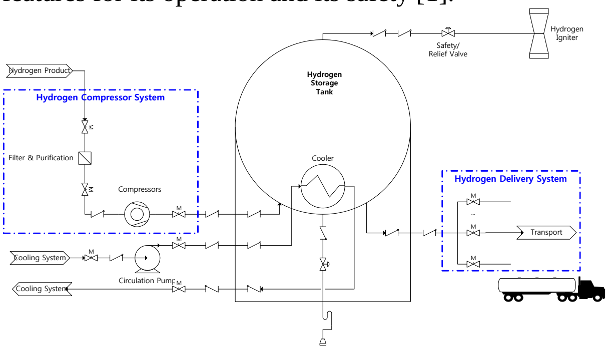

Fig.3. A conceptual diagram of the hydrogen storage system

In order to identify the accident sequences of a large scale leak of hydrogen gas and their likelihood, the nominal PSA approach was applied in an initiating events analysis, an accident progression analysis.

A MLD method was applied in the identification of initiating events (Fig. 4). For the accident progression analysis, an accident progression event tree method was applied (Fig. 5 & 6).

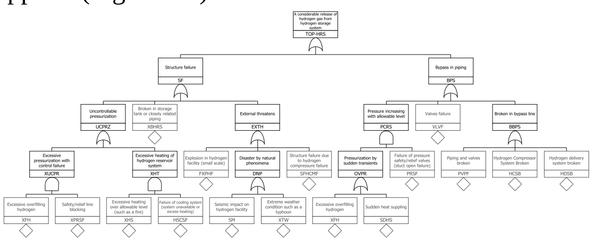

Fig.4. A MLD for a large scale release of hydrogen gas

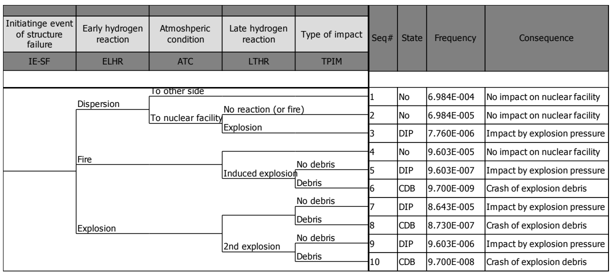

Fig. 5. An accident progression event tree for the structure failure (AP1)

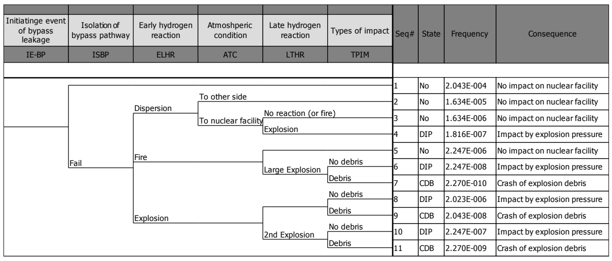

Fig.6. An accident progression event tree for the bypass events (AP2)

Each accident sequence was grouped into the three end states (No damage: NO, explosion pressure: DIP, & debris impact: IDB). In this study, as feasibility, subjective methods were applied in the assignment of their probabilities.

For each accident progression event tree, the quantification results of the structure failure (AP1) and the bypass events (AP2) were shown in Table 2 and Table 3, respectively.

Table 2. Quantification results of the end states for the AP1

End state	Frequency (1/yr)	Conditional Probability
No	8.64E-04	0.891
DIP	1.05E-04	0.108
IDB	9.80E-07	0.001

Table 3. Quantification results of the end states for the AP2

End state	Frequency (1/yr)	Conditional Probability
No	2.25E-04	0.989
DIP	2.45E-06	0.011
IDB	2.29E-08	0.000

3. Concluding Remarks

As a preliminary work, this study has identified a large scale leak of hydrogen from the hydrogen storage system as a major potential threat factor of the nuclear facility. The obtained insights can provide useful information to resolve the safety issues which will address the interfacing events between the nuclear and non-nuclear facilities. In order to obtain an applicability of this study, it is necessary to perform additional works for a consequence analysis of a large scale hydrogen leak in the near future.

Acknowledgements

This work was supported by Nuclear Research & Development Program of the Korea Science and Engineering Foundation (KOSEF) grant funded by the Korean government (MEST).

REFERENCES

[1] Jose Luis Aprea, Hydrogen energy demonstration plant in Patagonia: Description and safety issues, International Journal of Hydrogen Energy, Vol.34-10, p.4684-4691, 2009.

[1] In order to perform its risk assessment based on this conceptual diagram, many kinds of the design specifications including normal and abnormal operation procedures should be considered.