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A risk impact due to an ATWS accident sequence for a Korean PWR

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1. Introduction

Anticipated transient without scram (ATWS) event is a large risk impact accident sequence, while it is a beyond design basis accident. Recently, an accident analysis of an ATWS event for a domestic commercial nuclear power plant has been performed by an engineering company [1]. From this analysis results, we expect that an ATWS accident sequence for that plant will have a large risk impact. The present paper has studied an estimation of a risk due to an ATWS accident sequence for that plant by considering the recent accident analysis results.

Several estimation methods of a risk due to an ATWS accident sequence have been proposed by each probabilistic safety assessment (PSA). However, the general features of the estimation methods include the basic frame of the SECY-83-293 estimation method of U.S. NRC [2]. In this study, an estimation of the risk impact based on the SECY-83-293 model has been performed.

2. Estimation Method

In the SECY-83-293 estimation model, a basis of the risk estimation of an ATWS accident sequence is that a core damage is assumed because the reactor coolant system (RCS) pressure is over a specific acceptance criterion of the RCS pressure boundary during a specific transient event such as an ATWS event.

U.S. NRC has proposed the 'ASME level C stress limits (3200psi)' of a pressure vessel as a reasonable acceptance criterion [2]. What a pressure level is and what an adequate acceptance criterion is has been argued by several nuclear industrial engineers, but generally, U.S. NRC's proposed criterion has been accepted [3].

Under a typical ATWS event, the RCS is rapidly over-pressurized by the disturbance of the heat balance between the primary and the secondary systems. This rapid over-pressurization is affected by several essential system statuses (i.e., feedwater system, turbine system, etc) and the physical characteristics of reactor core, i.e., moderator temperature coefficient (MTC).

A risk impact due to an ATWS accident sequence has been mainly influenced by a reactivity feedback effect known as MTC. Especially, because the MTC changes according to the fuel burnup, the RCS pressure can rise to over the acceptance criterion only during a particular period in a fuel cycle when an ATWS event occurs. This particular period is defined as an unfavorable exposure time (UET). The UET is a time to an over-pressurizing of the RCS when an ATWS event occurs. The UET can be changed by several effects such as system configurations. In the current study, a variation of the risk impact according to the UET has been estimated so that we can try to identify the entire risk impact due to an ATWS accident sequence.

In the SECY-83-293 estimation, the CDF can be estimated by a detailed model by considering several factors that affect a RCS pressurization. There influence factors consist of an initiator, turbine status, electrical failure of a reactor protection system (RPS), a mechanical failure of RPS, UET estimation due to the MTC value, auxiliary feedwater system unavailability and a boron injection by a coolant makeup system.

3. Estimation of a Risk Impact

A reliability for each influence factor can be easily estimated by using current PSA results [4]. These estimations for each factor are as follows:

- Initiator: Initiators of an ATWS event in a risk estimation include all transient events that can happen to a reactor trip failure, while the meaning of an 'anticipated event' from a viewpoint of the accident analysis is an event that is expected to occur one or more times during a life of the plant. The estimation results for a domestic commercial nuclear power plant are shown in the forth-major column in Table 1.
- Turbine status: ATWS transient can be affected by the availability of a main feedwater supply. Thus, the main feedwater availability should be considered. In the SECY-83-293 estimation, about 30% of the total transient event was unavailable events of the main feedwater supply. Detailed estimation results are shown in Table 1.
- Failure of a RPS: A failure of a RPS for a reactor trip requirement can be divided as an electrical failure or a mechanical failure. The electrical failure can be estimated by the current PSA model. Mechanical failure of a RPS is due to a reactor control and shutdown rods insertion failure. This estimation has been referred to from the industrial report.
- Estimation and influence of UET: Over pressure frequency due to the UET value is a major part of the ATWS risk estimation. In the SECY-83-293 estimation model, the accident sequences of an ATWS are classified as three types: most, medium and less effect cases. In the most effect case, the over pressure frequency due to an UET corresponds to the ATWS accident analysis results. In the other cases, it is expected that the over pressure frequency is less than that of the most effect case.

- Auxiliary feedwater availability: In the case of the auxiliary feedwater system available, the RCS over pressurization can be relieved by an auxiliary feedwater supply. The example plant requires each auxiliary feedwater for each steam generator within about one or two minutes. This plant has installed an ATWS mitigation system called a diverse protection system (DPS) according to the domestic ATWS mitigation rule. This system can supply an auxiliary feedwater when an ATWS event occurs.
- Boric water injection by a coolant makeup system: Boron injection is required because of a long-term reactor safety. If a boric water injection by the coolant makeup system fails, an excessive reactivity insertion due to an unknown plant transient behavior cannot be effectively suppressed. Thus, a boron injection is an essential considering factor of the ATWS risk estimation. In the example case, operator should inject boric water within 10 minutes. Human error factor according to this mission time is estimated as 0.05.

4. Results and Discussion

An estimation result of a risk impact due to an ATWS accident sequence is shown in Table 2. As shown in Fig. 1, the overall risk spectrum by the UET variation for the example case is bounded between 7.80E-7/yr to 8.00E-6/yr. Each line in Fig. 1 shows a CDF variation due to the UET value of the medium and less effect sequence according to the limiting UET value of the most effect sequence. Using Fig. 1, the overall risk impact due to an ATWS accident sequence for the example plant can be identified by the UET estimation results.

4. Concluding Remark

In this paper, we tried to estimate the risk impact due to an ATWS accident sequence for a domestic nuclear power plant based on recent accident analysis results. As result of the current study, the risk from an ATWS accident sequence has been identified as a considerable impact on the entire risk of the example plant, so the risk estimation of that plant should be upgraded by considering the recent information like the ATWS accident analysis results. Finally, we expect that this study can become a basis for the entire risk estimation of the referred plant.

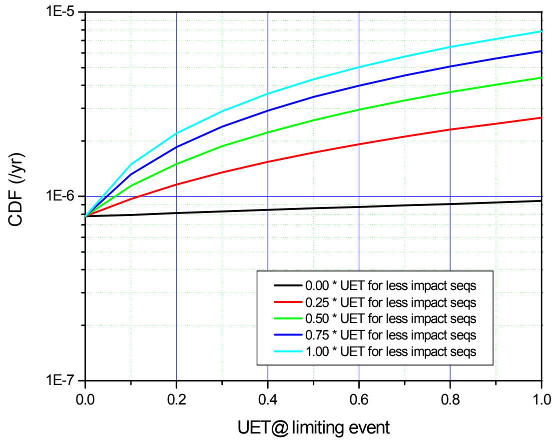

Fig. 1. Risk spectrum by UET variation for the example case

REFERENCES

[1] Lee, Sangil, "ATWS analysis for UCN 5&6," The first symposium of nuclear safety analysis, organized by KINS, Deachon, 2003 6.26-27, 2003

[2] U.S. NRC, SECY-83-293, 1983

[3] A.C. Thadani & E.W. Hagen, "Anticipated Transients without scram for light-water reactors," Nuclear Safety, Vol. 20, No. 4, 1979

[4] KOPCO, *Ulchin units 3&4 Probabilistic safety Assessment*, 1998

Table 1. Summary of turbine bypass initiator frequency ratio for an ATWS risk estimation

Initiator		Domestic Experience (PWR)			PRiMe V1.0	UCL 3/4	NUREG/CR-5750		EPRI URD
		Ry	# of Trips	MLE (f/N)			IPF	FI	
GTRNs without turbine bypass	LOFW	135.24	21	1.55E-01	8.40E-02	5.40E-01	5.44E-02	8.45E-02	4.60E-01
	LOCV	135.24	23	1.70E-01	4.90E-02	2.36E-01	3.76E-02	1.17E-01	0.00E+00
	LOOP	135.24	8	5.92E-02	3.00E-02	6.15E-02	2.37E-02	4.61E-02	3.50E-02
	Sum	135.24	52	3.85E-01	1.63E-01	8.38E-01	1.16E-01	2.48E-01	4.95E-01
GTRNs with turbine bypass		135.24	140.3	1.04	0.95	3	0.97	1.2	2.8
Total GTRN		135.24	244.3	1.42	1.11	3.84	1.09	1.45	3.3
Ratio (in SECY-83-293: 30%)				27%	15%	22%	11%	17%	15%

Table 2. Risk impacts of an ATWS accident sequence for the example plant

	SECY-83-293			Example plant (Plant-Specific)			
	Base Case	DSS + AMSAC	0.1 UET + DPS	Base	0.36 UET	0.12 UET	0.01 UET
Initiator (/ry)	4.0×0.7	4.0 ×0.7	4.0 ×0.7	1.4×0.73	1.4×0.73	1.4×0.73	1.4×0.73
RPS Electrical	2.E-05	2.E-06	2E-06	6.62E-6	6.62E-6	6.62E-6	6.62E-6
RPS Mechanical	1.E-05	1.E-05	1.E-05	5.0E-6	5.0E-6	5.0E-6	5.0E-6
(UET) MTC OPF - RPS (E) - RPS (M)	 0.5/1.0 0.5	 0.5 0.5	 0.1 0.1	 0.5 0.5	 0.05/0.36 0.05	 0.05/0.12 0.05	 0.01/0.01 0.01
AFWS - RPS (E) - RPS (M)	 0.16(manual fail) 0.04	 0.04 0.04	 0.04 0.04	 0.04 0.04	 0.04 0.04	 0.04 0.04	 0.04 0.04
HPI	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total	8.0E-5	2.2E-5	4.4E-6	8.6E-6	3.61E-6	1.49E-6	8.21E-7