The Sensitivity Study of the Usefulness of External Injection into RCS at SMART

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1. Introduction

In March 11, 2011, a great earthquake occurred at the north east coast of Japan. The accompanied tsunami swept the north east coast of Japan. As results of the tsunami Fukushima daichi nuclear power plants experienced long term station blackout and severe core damages and released a large amount of radioactive materials outside of the plants. Just after this accident Korean government organized a special inspection team and examined all the nuclear power plant carefully the resistance to the extreme conditions. One of the expert groups had suggested the following actions regarding on the severe accident prevention and mitigation.

- Provide the external injection path(s) to the RCS
- Provide the external injection path(s) to the steam generator
- Strengthen a training program for the severe accident management

SMART (**S**ystem integrated **M**odular **A**dvanced **R**eac**T**or) which is being developed by the Korea Atomic Energy Research Institute (KAERI), is under the regulatory review to obtain a standard design approval. During this review process, a regulatory authority asked to implement the post Fukushima actions announced by the government into SMART. This paper discusses the usefulness of the post Fukushima actions on the point of the core damage frequency.

2. Methods and Results

2.1 Prerequisites for the prevention of core damage

There are three prerequisites to prevent a core damage. First, there is a proper means to remove a decay heat generated in the core. SMART has a passive decay heat removal system (PRHRS), which operates when a feedwater to the steam generator is lost. The reliability of the PRHRS is very high because it operates by the natural forces, not the electricity. So the external injection into the steam generator is useless in SMART. External pump such as fire engine, may inject water into the reactor vessel if a proper path is provided and the primary pressure is lower than shutoff head of the external pump. SMART has a safety depressurization system (SDS) and will provide an external path enabling external injection in to the reactor vessel. Second, there is an instruction to use this means. At this time, an emergency operating procedure (EOP) does not reflect this alternative injection means. EOP will be revised to reflect the external injection. Finally, there is enough time to align the path of the external injection before the core damage. This pathway will be aligned manually according to the EOP.

The failure probability of the external injection into the reactor vessel depends on the design of the injection path, an available time to align the injection path, and the degree of the operator understanding of the EOG and skill.

2.2 Station Blackout Accident

In Fukushima NPP accident all the AC powers were lost for a long time. This accident is called a station blackout accident (SBO). For this accident, if PRHRS fail, the only way to avoid a core damage is the feed and bleed operation. The bleed of primary system is done by SDS and feed is done safety injection pump usually. SDS valve requires DC power to open. During a SBO, the safety injection pumps can't operate. So a fire engine may supply the water into the reactor vessel. A MIDAS/SMR code is used to find out how much times are available to avoid core damage[1]. The result of MIDAS/SMR calculation for which a SDS valve opened 2 hours after first primary safety valve (PSV) is summarized in Table 1. If two SDS valves open, the primary pressure decreases more rapidly. The conditional core damage frequency for SBO depends on the availability of DC power when a SDS valve is requested to open and the failure of the plant staff actions to injection water using fire engine.

2.3 Small Break Loss of Coolant Accident

A small break loss of coolant accident (SLOCA) was determined an important accident for SMART[2]. SLOCA contributes 35.2% of the total CDF. Among various core damage sequences for SLOCA, the failure of coolant injection into the reactor vessel by safety injection pump or shutdown cooling pump while the PRHRS is working, is determined the most important sequence. This sequence occupies 35.1% of the total CDF. A MIDAS/SMR code is used to find out how much times are available to avoid core damage. The result of MIDAS/SMR calculation is also summarized in

Table 1. As shown in Table 1, the available time for the operator actions to avoid the core damage is sufficient. This comes from a plenty coolant inventory compared to the thermal power. This is a big advantage of the integral reactor. The failure probability of the external injection into the reactor vessel depends on the design of the injection path, an available time to align the injection path, and the degree of the operator understanding of the EOG and skill. At this time the information which affects the failure probability of the external injection, is unavailable except the available time to the operator. So a sensitivity study is done on the failure probability of the external injection. The result is summarized in Table 2. As shown in Table 2, the external injection is very useful in preventing the core damage. When the failure probably is 0.1, the CDF for SLOCA reduces to almost 0.1 of the no external injection and contribution to the total CDF occupies only 5.2%. If the failure probably is 0.01, then the risk due to the SLOCA becomes negligible. It occupies less than 1% of the total CDF.

3. Conclusions

The usefulness of the external injection is examined. It is determined very effective in reducing risk due to SLOCA. If the external injection is reflected on the entire PSA model, then the total CDF of SMART will be reduced significantly. It is important that the procedures for the external injection should be written clearly on the EOP and the operators should be familiarized for this procedure. The degree of risk reduction depends on these two actions.

REFERENCES

[1] Software verification and validation report (MIDAS/SMR Ver.1.0.2), SMT-SVVR-TH-11003, Rev.00, KAERI, 2011
[2] T.W. Kim, et.al., Accident sequence quantification, 916-NS301-018, Rev.01, KAERI, 2010

Table 1. Important times for various accident sequences (unit : seconds)

	SBO w/ SDS	LOCA	
		50 mm	13 mm
Reactor trip	0.0	35	2,164
SDS open	12,144	-	-
Core uncover	21,090	4,494	127,103
RCS P < 2.8 MPa	20,529	3,376	80,171
RCS P < 1.0 MPa	34,800	8,700	>200,000
Cladding T > 1800 ^{o}F	31,278	15,141	>200,000

Table 2. Risk frequency for small LOCA

	Failure probability of the external injection		
	1.0	0.1	0.01
Conditional Probability	4.580E-06	4.562E-06	4.718E-07
Risk Frequency	1.818E-07	1.811E-08	1.873E-09
Contribution to total CDF	35.3%	5.2%	0.6%