Preliminary RTNSS Analysis for SMART

Jin Hee Park [a*], Yong Hoon Jung [a], Young-A Suh[b]
[a]*Korea Atomic Energy Research Institute*
[b]*Korea Institute of Nuclear Safety*
[*]*Corresponding author: jhpark6@kaeri.re.kr*

1. Introduction

The passive reactors such as SMART (System integrated Modular Advanced ReacTor), AP 600, AP 1000 have been developed in the world, adopted the passive safety systems that rely on natural forces such as density differences, gravity, and stored energy to provide water for core and containment cooling. Those passive reactors have the active non-safety systems to replenish passive system functions or to maintain long-term cooling for core and containment also. The residual uncertainties associated with those passive safety systems performance increase the importance of non-safety active systems to back up the passive safety systems. Resolving this issue, the US NRC and EPRI initiated a process to identify important active systems and to maintain appropriate regulatory oversight of those systems. During this process, the NRC issued Regulatory Guide 1.206 C.IV.9 and approved the regulatory treatment of non-safety systems (RTNSS) process [1,2]. In this study, the preliminary RTNSS process to identify important non-safety systems for SMART is presented.

2. RTNSS Process for SMART

The RTNSS main process is classified three steps as follows.

1) Identification of the significant non-safety related SSCs
2) Development of special reliability/unavailability mission for the significant non-safety related SSCs
3) Specification of proposed regulatory treatment for each of the mission developed

The US RTNSS process suggest probabilistic and deterministic approaches for above three steps.

The preliminary RTNSS process for SMART has been conducted by probabilistic and deterministic methods to identify significant non-safety SSCs (Structures, Systems and Components) based on the US RTNSS process [3]. In this study, we are focusing the first step and the others would be provided from detailed design and construction stages for SMART.

2.1 Probabilistic RTNSS approach for SMART

The focused full power probabilistic safety assessment (PSA, PRA) sensitivity analysis and the initiating event frequency evaluation are applied for the SMRT RTNSS process.

The LPSD (Low Power and Shut Down) PSA is not included in this study because the LPSD PSA has not performed for SMART.

In the focused PRA sensitivity analysis, the core damage frequency (CDF) and large release frequency (LRF) are recalculated assuming non-safety related SSCs failed (not credit for accident mitigation) to mitigate accident sequence on original SMART PSA [4]. Non-safety SSCs are not considered important for PSA mitigation if the recalculated CDF and LRF is less than regulatory safety goal.

The excluding non-safety systems for the focused PSA recalculation for SMART are as follows.

- Component Cooling Water System/Service Water System
- Chemical and Volume Control System
- Diverse Protection System
- Standby Diesel Generator

As the PSA sensitivity analysis results, the recalculated CDF and LRF are meet domestic and NRC's safety goal and any important non-safety SSCs is not identified.

And, the evaluation is performed to identify important non-safety related SSCs that their unavailability would affect to the initiating events (IEs) frequencies significantly for SMART PSA also. Total of 22 internal initiating events for full power PSA are reevaluated based on three criteria to determine the importance of the non-safety SSCs as follows.

- Consideration of non-safety SSCs for calculation IE frequency
- Consideration of the unavailability of non-safety SSCs for calculation IE frequency
- Consideration the IEs contribution for CDF/LRF (higher than 10% is significant)

For each initiating event, if the response to any one of the three criteria is "No," then the unavailability of the non-safety related SSCs is not important to the calculation of initiating event frequency for the PRA.

As the IE reevaluation results are summarized in table 1 and any non-safety SSCs is not identified.

Table1: IEs Revaluation Results

IEs	Criteria 1	Criteria 2	Criteria 3
LOCA	No	N/A	N/A
Secondaty Pipe Break	No	N/A	N/A
General Transient	Yes	Yes	Yes
Support Susye IE	Yes	Yes	No
LOOP	Yes	Yes	Yes

2.2 Deterministic RTNSS approach for SMART

The RTNSS process requires to meet six deterministic requirements applied for active reactor as follows also.

- Anticipated transient without scram (ATWS) rule (10 CFR 50.62)
- Loss of all ac power rule (10 CFR 50.63)
- Post-72hour actions
- Containment performance
- Adverse interactions with safety-related SSCs
- Seismic considerations

The design review analyses are performed to check if SMART design could meet above those requirements.

The first rule for reduction of risk from ATWS accident, requires diverse actuation of auxiliary feedwater (for decay heat removal) and turbine trip. The SMART design adopts DPS (Diverse Protection System), that trips the reactor/turbine and actuates PRHRS (Passive Residual Heat Removal System) to provide decay heat removal. The main component of DPS are designed non-safety grade and supported by non-class 1E DC (Direct Current) power.

The second rule requires the capabilities to safely shut down SMART reactor after loss of all AC (Alternating Current) power. The SMART design could establish safe shut down reactor and maintain safe shut down condition using on site class 1E DC power for 72hrs following loss of all ac power accident. After 72hrs, two non-safety ADGs (Ancillary Diesel Generator) are provided for class 1E DC power back up.

The third rule requires the capabilities to maintain safe shutdown condition SMART reactor post 72 hrs. The SMART design adopted 2 ECT (Emergency Cooldown Tank) back up tank and two non-safety SIT (Safety Injection Tank) refill pumps supported by ADG and related support systems for post 72 hrs.

The containment performance requirement is dealt in focused PSA approach and excluded in deterministic process. The potential adverse system interaction between safety systems and non-safety systems are considered in SMART system design stage and excluded in deterministic process also.

The last rule is for the capabilities to safely shut down a SMART reactor for seismic events. The safety related mitigation system for 72 hrs following seismic event and their back up non-safety SSCs are designed in accordance with SMART seismic design criteria. So, any non-safety SSCs except ADG is not identified for seismic consideration requirements.

As the SMART deterministic RTNSS analysis results, some non-safety SSCs are identified for important non-safety SSCs to plant risk and summarized in table 2.

Table 2: The Deterministic Analysis Results

SSCs/Function	Determinist c Critera	Related component	Remarks
DPS	10CFR 50.62	-Processor Sensor/indicator	final RTNSS evaluation neeed
		-Cabinet	
		Supporting system	
Ancillary D/G	10CFR50.63	-Ancillary D/G	N/A
	Post-72Hr Action/Seismic Consideration	-Supporting sysytem(fuel, control & HVAC, etc)	
Long-term Cooling	Post-72Hr Action	-ECT Back up system	final RTNSS evaluation neeed
		IRWST Recirculation System	
		MCR habitabilty/Post accident monitoring system	
		SIT Recirculation sysytem	

3. Conclusions

The preliminary RTNSS process for SMART has been conducted by probabilistic and deterministic methods to identify non-safety class SSCs based on US methodology. As a result of the RTNSS process for SMART, some non-safety SSCs are identified for important non-safety SSCs to plant risk. The reliability/availability assurance program for those non-safety SSCs would be established during the SMART construction stage and this study could be used for that basic RTNSS evaluation method. And the RTNSS process for domestic passive reactor must be provided also.

Acknowledgment

This study has been carried out under the national Nuclear R&D Program by Ministry of Science and ICT in Korea

REFERENCES

[1] U.S. NRC “Combined License Applications for Nuclear Power Plants (LWR Edition),” Regulatory Guide 1.206, C.IV.9, Regulatory Treatment of Non-safety Systems June 2007, ADAMS Accession No. ML070720184., 2002.
[2] AP1000 Implementation of the Regulatory Treatment of Non-safety Related Systems Process, WCAP-15985, November 2002.
[3] KAERI, Regulatory Treatment of Non-safety Systems for SMART, KAERI/TR-8496/2020, December. 2020.
[4] KAERI, SMART PSA Report, December. 2019.