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iPOWER Regulatory Treatment of Non-Safety System

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1. Introduction

For the most of nuclear power plants, they use active systems classified as safety related to provide accident prevention and mitigation functions. In case of the passive plants, above active systems are replaced by the passive systems and only they are classified as safety related.

Consequently, active systems not to be credited for accident mitigating functions on DBA (Design Basis Accident) are non-safety related systems. However, certain non-safety related active systems in the passive plants provide defense-in-depth functions, secure the safety margin of the safety related passive system, and perform functions to compensate for the uncertainty. And these non-safety related active systems require a high level of confidence.

In the US, the NRC and EPRI have developed a process for maintaining appropriate regulatory oversight of these active systems in the passive plants. This process which is introduced to eliminate the inherent uncertainty of the passive system is called 'RTNSS (Regulatory Treatment of Non-Safety System)'.

In this paper, the selection of RTNSS candidates for the iPOWER (Innovative Passive Optimized Worldwide Economic Reactor) according to SRP 19.3[1] is introduced. Since iPOWER design is in the conceptual phase, specific detail design information and procedures are not sufficiently developed yet. Therefore, the review is conducted based on the design information and assumptions available at this time. The RTNSS SSCs (System, Structure, and Component) can be changed in the future according to changes in the detail design and operating strategy.

2. Methods

The inherent uncertainties associated with passive safety system performance increase the importance of active systems in providing defense-in-depth functions to the passive systems. The study on RTNSS is started in the early 90s through AP600 licensing process. Fig. 1 shows the process.

Since 2003, RTNSS related licensing process for AP1000 has been started, and research continued for GE's ESBWR from 2004 to the early 2010s.

According to SECY 94-084[2] and SRP 19.3, The RTNSS process applies broadly to those non-safety related SSCs that perform risk significant functions and, therefore, are candidates for regulatory oversight.

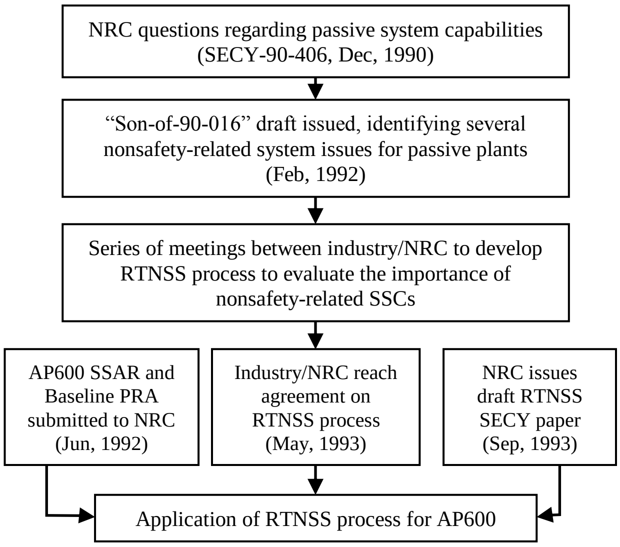

Fig. 1. History of RTNSS process for AP600[3]

The RTNSS process uses the following five criteria to determine those SSC functions:

A. SSC functions relied on to meet beyond design basis deterministic NRC performance requirements such as those set forth in Title 10 of the Code of Federal Regulations (10 CFR) 50.62[4] for mitigating Anticipated Transients Without Scram (ATWS) and in 10 CFR 50.63[5] for Station Blackout (SBO).

B. SSC functions relied on to ensure long-term safety (the period beginning 72 hours after a design basis event and lasting the following 4 days) and to address seismic events.

C. SSC functions relied on under power-operating and shutdown conditions to meet the Commission goals of a core damage frequency (CDF) of less than $1x10^{-4}$ each reactor year and a large release frequency (LRF) of less than $1x10^{-6}$ each reactor year.

D. SSC functions needed to meet the containment performance goal, including containment bypass, during severe accidents.

E. SSC functions relied on to prevent significant adverse systems interactions between passive safety systems and active non-safety SSCs.

3. Results

Based on SRP 19.3 and referring to the cases of AP1000 and ESBWR, iPOWER RTNSS classification is reviewed. The results are based on the information available at this conceptual design phase.

A. RTNSS Criterion A

1) Anticipated Transient without Scram (ATWS)

To ensure the reactor shutdown and passive auxiliary feedwater function under ATWS condition, iPOWER is designed with Diverse Protection System (DPS) that can provide an independent reactor shutdown function and an auxiliary water supply function separated from the Reactor Protection System. Therefore, the RTNSS SSCs are as below.

- At power operation, DPS functions to actuate reactor trip, turbine trip and PAFS (Passive Auxiliary Feedwater System)
- Functions supporting DPS with non-safety A/C power and UPS (Uninterruptible Power Supply)

2) Station Blackout (SBO)

iPOWER is designed such that no operator actions or AC power are required for a station blackout (SBO) event for 72 hours. Since safety related SSCs are battery powered, iPOWER is designed to successfully mitigate an SBO event to meet the requirements of 10 CFR 50.63 using only safety related passive SSCs. There are no RTNSS candidates for SBO based on Criterion A

B. RTNSS Criterion B

1) Long-term Safety

iPOWER is designed so that safety related passive systems are able to perform all safety functions for 72 hours, after initiation of a DBA, without the active systems or operator actions. After 72 hours, non-safety related systems are used to replenish the passive systems or to perform core cooling and maintain containment integrity directly. Between 72 hours and seven days, the resources for performing safety functions must be available on-site.

Safety functions required after 72 hours are shown on Table 1 and the systems providing these functions are candidates for RTNSS

Table 1. RTNSS SSCs for Long-term Safety

a) Core Cooling, Inventory and Reactivity Control and Containment Cooling and Ultimate Heat Sink Implementation: Core cooling is performed via gravity drain from the hybrid-SIT, SIT, IRWST of PECCS and/or natural circulation HX connected to SG of PAFS. Containment cooling is also performed via natural circulation of air and evaporation of water on inner surface of HX in PCCS. PCCT has a role as water source of PAFS/PCCS and a sufficient inventory to perform safety functions for 3 days. After 3 days, following non-safety related SSCs are required to compensate PCCT inventory. SSCs: - Alternative Ancillary Pump (AAP), piping and pump - Condensate Storage Tank (CST) - Ancillary A/C Generator, Fuel Storage Tank - MCR, Instrument/Electrical Control Room HVAC
b) Control Room Habitability Implementation: The passive emergency HVAC system with compressed air in the MCR controls the air for the first 3 days. After 3 days, the MCR ancillary fans can be used to circulate ambient air through the MCR to provide cooling. SSCs: - MCR Ancillary Fan - Ancillary A/C Generator, Fuel Storage Tank
c) Post-Accident Monitoring Implementation: AC power is required to provide non-safety related means of supplying power to post-accident monitoring. SSCs: - High/Low voltage Control Panel - Motor Control Panel - Ancillary A/C Generator, Fuel Storage Tank
d) Spent Fuel Pool (SFP) Cooling Implementation: Passive SFP cooling is performed by evaporation of normal SFP water inventory for 3 days. After 3 days, SFP can be replenished from PCCT. AAP provides long-term shutdown support by compensating water to PCCT and SFP. The PCCT volume is sufficient to maintain SFP cooling during 3 to 7 day time period following an accident. SSCs: - AAP, piping and pump - Ancillary A/C Generator, Fuel Storage Tank

* IRWST: In-containment Refueling Water Storage Tank
* PECCS: Passive Emergency Core Cooling System
* PCCS: Passive Containment Cooling System
* PCCT: Passive Condensate Cooling Tank

2) Seismic Event

According to KINS/RG-N4.29[6] Ch.8 and NRC DC/COL-ISG-020[7], as a result of PSA-based SMA (Seismic Margin Assessment), the design-specific plant-level HCLPF (High Confidence of Low Probability of Failure) value should be demonstrated to be equal to or greater than 1.67 times the SSE (Safe Shutdown Earthquake).

In the case of AP1000, non-safety related SSCs are not considered in SMA and SSCs considered in DBA are designed according to seismic design criteria.

For iPOWER, the evaluation results cannot be confirmed because the SMA is not carried out yet. However, if it is designed to have the equal to or higher level of safety than AP1000, there will be no RTNSS candidates for seismic event.

C. RTNSS Criterion C

1) PSA Mitigation Evaluation

The focused PSA is a sensitivity study based on a model of safety related systems, with additional consideration of the non-safety related active systems required to meet performance goals.

Table 2 shows that which systems are considered for the focused PSA and Table 3 shows the focused PSA results.

Table 2. Considered Systems for Focused PSA

Safety Related Systems Mitigating Accident	- PECCS - ADS (Automatic Depression System) - PAFS - PCCS
Non-safety Related Systems Considered to Meet Goal	- SI (Safety Injection System) - SC (Shutdown Cooling System) - AF (Auxiliary Feedwater System) - CS (Containment Spray System)

Table 3. Focused PSA Results

	At Power Level 1 Internal Event PSA Results	
	Safety Systems only	Safety Systems + SI
CDF	1.55×10^{-5} / yr	9.49×10^{-7} / yr
Goal*	1.00×10^{-6} / yr	

*Since iPOWER design is in conceptual phase, the goal is conservatively set 1/10 of requirements.

As a result of assessment (Table 3), when the only safety related passive systems are used to mitigate the accident, the CDF value is 1.55×10^{-5}/yr and the performance goal is not met.

In order to meet goal, sensitivity analysis was additionally conducted with various combinations of non-safety related systems. Consequently, If SI providing function of reactor coolant heat removal, pressure and inventory control is added to the focused PSA, CDF value (9.49×10^{-7}/yr) meets the performance goal.

Therefore, SI is designated as RTNSS for PSA mitigation.

2) PSA Initiating Event Frequency Evaluation

Based on following 3 criteria, PSA initiating event frequency evaluation is to determine RTNSS candidates by determining whether non-safety related SSCs could have a significant effect on the estimated frequency of initiating events.

○ Criterion 1: Are non-safety related SSCs considered in the calculation of the initiating event frequency?

○ Criterion 2: Does the unavailability of the non-safety related SSCs significantly affect the calculation of the initiating event frequency?

○ Criterion 3: Does the initiating event significantly affect CDF or LRF for the baseline PRA?

As a result of evaluating the selected initial events at power operating condition, iPOWER has no initial event that meets all three criteria. Therefore, there are no RTNSS candidates for this category.

D. Containment Performance

When determining the RTNSS SSCs, containment performance criteria of SRP 19.3 shall be met as shown below.

○ The containment should maintain its role as a reliable, leak-tight barrier by ensuring that containment stresses do not exceed American Society of Mechanical Engineers service level C limits for a minimum period of 24 hours following the onset of core damage, and that following this 24-hour period the containment should continue to provide a barrier against the uncontrolled release of fission products.

○ The conditional containment failure probability determined from the Level II PSA is less than or equal to 0.1.

The RTNSS SSCs shall be determined for this criterion after level 2 PSA is carried out.

E. Adverse System Interaction

Adverse system interaction (ASI) is categorized in 3 type of interactions: functional, spatial, and human-intervention. ASI assessment is conducted to recognize the effect of non-safety related system on safety related passive system.

When the basic design of iPOWER is completed, ASI assessment will be performed. If there is an adverse impact on safety function, iPOWER will fundamentally exclude it through design changes. Therefore, it is considered that there are no RTNSS candidates under this criterion.

4. Conclusions

The RTNSS SSCs of iPOWER selected according to the above results is shown in Table 4.

Table 4. Selected iPOWER RTNSS SSCs

RTNSS Criterion	Results
A (ATWS, SBO)	- Diverse Protection System - Supporting System for DPS
B (Post-72 hr, Seismic)	- Alternative Ancillary Pump (AAP), piping and pump - Condensate Storage Tank (CST) - MCR, Instrument/Electrical Control Room HVAC - MCR Ancillary Fan

	- High/Low voltage Control Panel - Motor Control Panel - Ancillary A/C Generator, Fuel Storage Tank
C (PRA mitigation, initiating)	- Safety Injection System
D (Containment Performance)	- N/A
E (Adverse System Interaction)	- N/A

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REFERENCES

[1] NUREG-0800, Standard Review Plan 19.3, "Regulatory Treatment of Nonsafety Systems for Passive Advanced Light Water Reactors", Revision 0, 2014, US NRC.
[2] SECY-94-084, 1994, US NRC.
[3] WCAP-15985, "AP1000 Implementation of Regulatory Treatment of Nonsafety-Related Systems Process", Revision 2, 2003, Westinghouse.
[4] 10CFR50.62, "Requirements for Reduction of Risk from Anticipated Transients without Scram (ATWS) Events for Light-Water-Cooled Nuclear Power Plants", National Archives and Records Administration, U.S. Government Printing Office, Washington, DC.
[5] 10CFR50.63, "Loss of All Alternating Current Power, National Archives and Records Administration", U.S. Government Printing Office, Washington, DC.
[6] KINS/RG-N4.29, "Alternative Design Considerations for Exclusion of OSE Loads", 2019, KINS
[7] DC/COL-ISG-020, "Seismic Margin Analysis for New Reactors Based on Probabilistic Risk Assessment", 2009, US NRC