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Initial Conditions and Plant Protection System Setpoints for Safety Analysis in the SALUS

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1. Introduction

The SALUS (Small Advanced Long-cycled and Ultimate Safe sodium-cooled fast reactor) is a kind of small modular reactor (SMR) based on the SFR with a metal-fueled core that has an approximate 20-year refueling cycle. The SALUS, a typical pool-type SFR of 100MWe power, is a co-generation SMR that is capable of supplying electricity and heat to populated and remote areas [1]. And the SALUS has the inherent safety of the fast reactor, while the metal-fueled core ensures enhanced safety.

This paper presents the methodology for establishing the initial conditions and plant protection system (PPS) setpoints for a safety analysis in the SALUS.

2. Methods and Results

2.1 SALUS Design

The SALUS has two intermediate heat transport system (IHTS) loops, with one steam generator (SG) for each loop. As each loop constitutes a closed path transferring the thermal energy to the SG, any failures in the secondary loop do not directly deteriorate the safety of the primary loop. The core is loaded with U-10Zr metal fuels, and all the structures, systems, and components (SSCs) of the primary heat transport system (PHTS) are installed in a single reactor vessel. Table I illustrates the primary design parameters of the SALUS [2].

Table I: Major Design Parameters of SALUS

Parameters	Design Value
Thermal Power, MW	267 MW
Core Inlet Temperature	360°C
Core Outlet Temperature	510°C
Core Inlet Flow Rate	1366 kg/s
No. of Fuel Assembly	112 ea

2.2 Methods

The initial conditions for the major system parameters and the analysis trip setpoints of the PPS are determined by considering the limit conditions for operating (LCO), the measurement uncertainties, the PPS channel errors, and margins as depicted in Fig. 1 [3].

2.3 Initial Conditions for Major Parameters

Table II: Range of Initial Conditions for Major Parameters

Parameters	Initial Conditions		
	Lower	Nominal	Upper
Core Power		100%	102%
PHTS Flow	92%	100%	108%
Core Inlet Temp.	348°C	360°C	372°C
Core Outlet Temp.	1)	1)	1)
1) It is determined by power, PHTS flow and core inlet temperature.			

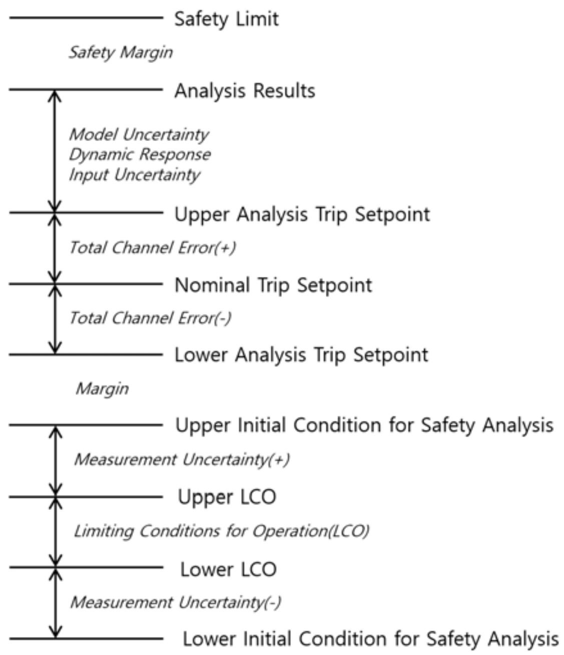

Fig. 1. Setting Initial Conditions and Analysis Setpoints

The range of initial conditions for the major parameters is established as shown in Table II.

An initial core power of 102% of full power is assumed to consider measurement uncertainty and conservative analysis. The PHTS flow range is set conservatively to ±8% of the rated flow considering the LCO for the power-to-flow-ratio (P/Q) and its associated measurement uncertainty. The core inlet coolant temperature range is determined to be ±12°C of the rated temperature considering the related measurement uncertainty. The coolant temperature range of the core outlet is defined by the temperature calculated based on the initial conditions of the PHTS flow and the core inlet coolant temperature. Nonetheless, the core outlet coolant temperature should cover the LCO for the core outlet coolant temperature.

Table III: Initial Condition Combinations

No.	Power	PHTS Flow	T_{in}	T_{out}
1	100%	100%	360℃	514℃
2	102%	92%	348℃	519℃
3	102%	92%	372℃	493℃
4	102%	108%	348℃	542℃
5	102%	108%	372℃	517℃

The combinations of the initial conditions for a safety analysis were selected as shown in Table III, with the scope for expanding the range for further sensitivity analyses if required.

2.4 Analytical PPS Setpoints

The analytical PPS setpoints are established as shown in Table IV.

Taking into account the channel uncertainty on the nominal P/Q setpoints of the PPS, the analysis trip setpoint for a high P/Q is set at 120%. The rated temperature at the outlet of the hot channel assembly is determined by the PHTS flow and the core inlet coolant temperature. However, to ensure a conservative approach in setting the analysis trip setpoints, the rated temperature at the outlet of the hot channel assembly is derived from the temperature under the conditions of the lowest PHTS flow and the highest core inlet coolant temperature (Case 4 as shown in Table IV). Consequently, the analysis trip setpoint for the high hot channel assembly outlet temperature (HCOT) is established at 566℃, which includes an addition of 24℃ to the rated temperature (542℃). The analysis trip setpoint for the high core inlet coolant temperature (CIT) is established at 384℃ with considering the total PPS channel uncertainty on the nominal trip setpoint. The overpower analysis setpoint is conservatively determined at 118% by taking into account the total PPS channel uncertainty.

Table IV: Analytical PPS Setpoints

Parameters	Nominal	Analysis	Function
High P/Q	116%	120%	Rx Trip
High HCOT	538℃	542℃	Rx Trip, ESF Actuation
High CIT	380℃	384℃	Rx Trip, ESF Actuation
Overpower	115%	118%	Rx Trip

3. Conclusions

This paper has established the initial conditions for the key parameters and the analytical PPS setpoints for a safety analysis in the SALUS. If the safety analysis results with the initial conditions and analysis PPS setpoints lead to a failure to meet the relevant acceptance criteria or need to additional safety margins, an adjustment in the initial conditions and the analysis PPS setpoints should be required.

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