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Preliminary Level 1 PSA Results for SFR-600 Conceptual Design

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1. Introduction

A sodium-cooled fast reactor (SFR), SFR-600, is under development at KAERI. Its fuel is the metal fuel of U-TRU-Zr and it uses sodium as coolant. Its advantages are found in the aspects of an excellent uranium resource utilization, inherent safety features, and non-proliferation. SFR-600 has passive safety features such as passive shutdown functions, passive pump coast-down features, and passive decay heat removal systems. It has inherent reactivity feedback effects. The probabilistic safety assessment (PSA) will be one of the initiating subjects for designing it from the aspects of a risk informed design (RID) as well as a technology-neutral licensing (TNL). Accident scenarios which lead to the core damage should be identified for the development of a Level-1 PSA model. Preliminary level 1 PSA models and the results for the metal fuel SFR-600 conceptual design are introduced here.

2. Preliminary Level-1 PSA Models and Results

The following background informations are used in the development of level-1 PSA models for SFR-600; Various PWR PSA reports, PRISM PSA report, Design information of KALIMER-600, KAERI/AR-799/2008, KAERI/TR-3741/2009.
Preliminary level-1 PSA models are developed for SFR-600 break-even reactor concept. Only internally initiated events are considered. Total 10 initiating events are modeled now. External events such as seismic and fire events are not considered yet. Level-2 PSA methodology is under development now. Level-3 PSA methodology will be developed at the next step of the mid and long term nuclear R&D program of Korean government. The safety functions considered are reactor shutdown function and decay heat removal function as shown in table 1. Inventory control and pressure control functions, which are usually considered in LWR PSAs, are not considered here. SFR-600 is vessel type (large sodium volume in reactor vessel) and operates in atmospheric pressure. Current generation LWRs is loop type and operates in about 150 atmospheric pressure. The design status of satety systems are as follows.
RPS : 3 diverse systems (primary control rods, secondary control rods, ultimate Shutdown System)
PDRC : safety grade, 50% x 2 trains
IRACS : non-safety grade, 100% x 2 trains
For supporting systems, only electrical power systems are considered now. It is assumed that the electrical power system has 2 redundancy trains and has a gas turbine generator in each train.
Component reliability data for the components which are common to LWR and SFR are selected from the EPRI URD and NUREG reports. For the components which are used in SFRs only are decided by engineering judgment.

Table 1. Comparison of Critical Safety Functions between SFR-600 and OPR1000

CSF	SFR-600	OPR1000
Reactivity	RPS (assume 2 group Diversity), USS	RPS, DPS
Inventory Control	Vessel Type	Safety Injection (High Pressure, SIT, Low Pressure)
Decay Heat Removal	PDRC (Passive) IRACS Normal Feedwater	AFWS (2 MDP + 2 TDP) Safety Injection + Bleed (SDS Valves) Normal Feedwater Startup Feedwater Pump
Pressure Control	Not Required	Pressurizer, PRV
Support Systems	EPS only	EPS, CCW, HVAC

Table 2. Initiating Events Frequencies and Relative Core Damage Frequencies Contributions for SFR-600

Initiating Event	IE Freq/yr	CDF(%)
General Transients	1.00E+00	25.58
Vessel Leak	1.00E-04	21.67
Sodium Water Reaction in SG	1.00E-03	20.84
PDRC Unavailable	3.00E-03	7.85
Loss of Primary Flow	3.00E-01	7.66
Loss of Secondary (Feedwater)	3.00E-01	7.66
Loss of Intermediate Flow	3.00E-01	7.66
Loss of Electric Power	3.00E-02	1.05
Reactivity Insertion Accident	1.00E-03	0.02
Fast Reactivity Insertion Accident	1.00E-10	0.01
Total		100

Table 2 shows initiating events frequencies and relative core damage frequencies contributions for SFR-600. Table 3 shows the results (increasing ratio of CDF to base case) of the various design alternatives on the safety systems.

ACKNOWLEDGEMENTS

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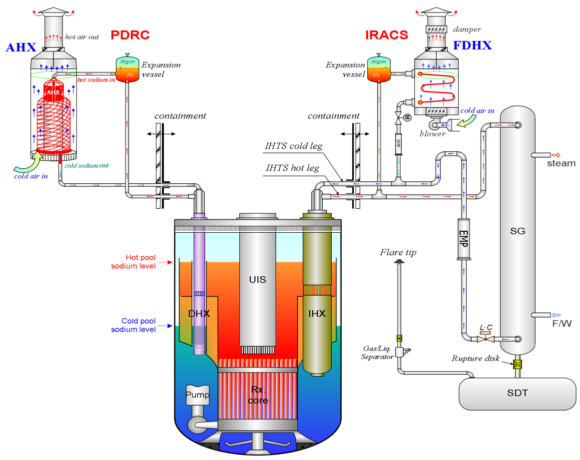

Fig. 1. A sketch of SFR-600 reactor vessel and decay heat removal systems (PDRC and IRACS)

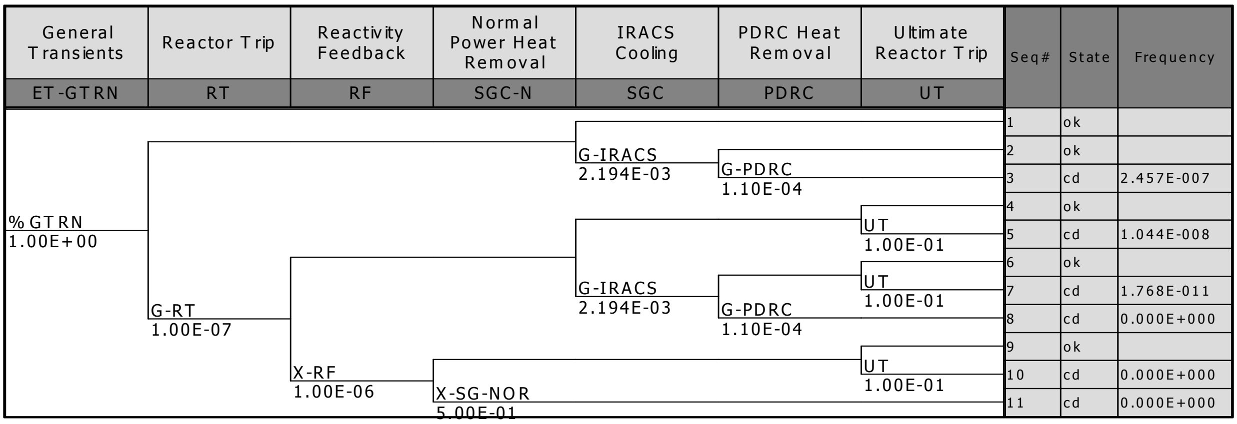

Fig. 2. An Example of Level 1 System Event Tree of General Transient Accident for SFR-600

Table 3. Sensitivity study results of the various design alternatives on the safety systems

System	Base Case Assumptions	Assumptions in Sensitivity Study	Increasing ratio
PDRC	PDRC	No PDRC	5176
	2 x 50% Passive	2 x 100% Active System	10.2
	Solidification frequency (0.003/yr)	10 times increase (0.03/yr)	1.76
	PDRC reliability (1e-4)	10 times increase (1e-3)	5.66
	2 x 50% Passive	2 x 100% Passive	0.86
IRACS	2 x 100%, Safety class electric power (2 Gas Turbine backup)	No IRACS	364
EPS	2 Gas Turbine backup	No Gas turbine	11.4
RPS	2 diverse systems (1st, 2nd)	No 2nd RPS	23.4