Safety Analysis of Single Feedwater Pump Seizure event for PGSFR using MARS-LMR

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1. Introduction

Korea Atomic Energy Research Institute(KAERI) has been developing the Prototype Generation IV Sodium Cooled Fast Reactor(PGSFR). In PGSFR, a sodium is used as a reactor coolant. To transfer the core heat to PCS(Power Conversion System), the PHTS (Primary Heat Transport System), the IHTS (Intermediate Heat Transport System) are designed. And the DHRS (Decay Heat Removal System) [1] which is to remove the core decay heat consists of the two ADHRS (Active Decay Heat Removal System) and two PDHRS (Passive Decay Heat Removal System). It is connected with four DHXs (Decay Heat eXchanger) immersed in the reactor vessel after a reactor shutdown.

In PGSFR, Loss Of Heat Sink (LOHS) events have a scenario not to remove the core heat from the IHTS or PCS normally. Single feedwater pump seizure event is selected as representative event for DBA Class-2. Safety evaluation is carried out with MARS-LMR code [2].

2. Safety Analysis Methodology

As an event occurrence frequency, LOHS events are categorized into the AOO, DBA Class-1, DBA Class-2 event. Single feedwater pump seizure event is included into the DBA Class-2. A safety acceptance criteria for DBA Class-2 is that sodium bulk temperature shall be under sodium boiling temperature [3].

For determistic safety analysis, the most conservative initial condition must be determined. During a normal operation, occurable the most severe plant condition in the range of LCO (Limiting Conditions for Operating) is determined by a senstivity analysis based on the mixture of the LCO parameters. And also the sensitivity analysis for core reactivity parameters such as a sodium coolant reactivity, doppler reactivity worth, fuel axial expansion reactivity, core radial expansion, control rod drive line and reactor vessel expansion is carried out. Initial core power for transient calculation is determined as a 102% considering the uncertainty of the core power detector. A few of conservative assumptions are considered. 1-train of two ADHRS is a failure as a single failure for active safety related component. 1-train of two PDHRS is a failure as a maintenance. LOOP (Loss of Offsite Power) is assumed to occur at the same time RPS trip signal. At 0.0 second, the affected feedwater flow rate is set to 0.0 kg/s to maximize the temperatures of the coolant, cladding, and fuel. Fig. 1 shows the MARS-LMR nodalization of IHTS for LOHS events. One of two IHTS loops consists of the two IHXs, hot leg, cold leg, one EM pump, one expansion tank, and one steam generator.

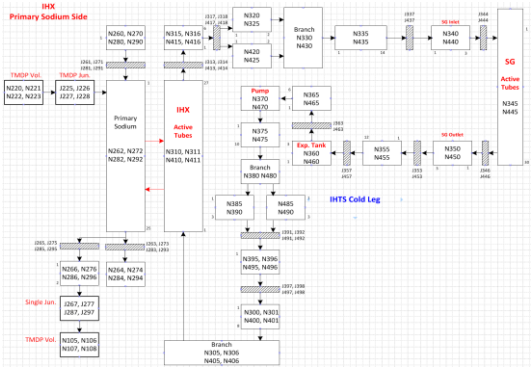

Fig. 1. IHTS MARS-LMR nodalization for LOHS events.

3. Safety Analysis Results

Single feedwater pump seizure event is initiated by the seizure of the feedwater pump bearing. Since the rotating shaft of the feedwater pump instantaneously stops, the feedwater flow rate is rapidly decreased. Because the heat of the affected IHTS sodium can not transferred to the affected steam generator, the coolant temperature in the core inlet increases. A reactor is tripped by the core inlet temperature RPS trip signal. The unaffected pumps of the PHTS, the IHTS, and the feedwater are stopped by the LOOP assumption. The dampers are fully opened and the blower of the DHRS are operated by the ESF(Engineering Safety Features) actuation signal to remove the core decay heat. For LOHS events, a reactor trips occurs by the core inlet temperature trip variable. And that have a similar event scenario and thermal hydraulic behavior. Table 1 shows the most conservative initial conditions and assumptions for this event. Table 2 shows the event sequence of single feedwater pump seizure.

Table 1 Assumptions and initial conditions for Single Feedwater Pump Seizure Event

Parameter	Value
Initial Power, MWt	400.0
Initial Core Inlet/Outlet Coolant Temperature, ℃	386.0 (Inlet) 549.0 (Outlet)
Initial Core Mass Flow, kg/sec	1931.2
RV Cover Gas Pressure, MPa	0.149
Doppler Reactivity	Least Negative

Coolant Density Reactivity	Least Negative
Core Axial Expansion Reactivity	Least Negative
Core Radial Expansion Reactivity	Least Negative
Control Drive Line and RV Expansion Reactivity	Least Negative
LOOP	At the same time, Reactor Trip Signal
Single Failure, Maintenance	1-Train Single Failure of ADHRS, 1-Train Maintenance of PDHRS

Table 2 Event Sequence of Single Feedwater Pump Seizure

Time (Sec)	Event	Setpoint or Value
0.0	Single Feedwater Pump Seizure Occurs	
128.78	High Core Inlet Temperature reaches Reactor Trip Setpoint, ℃	405
134.78	Reactor Trip Actuation Signal and Loss of Offsite Power Occur	
135.33	Insertion of Control Assemblies occurs	
154.88	DHRS Damper and Blower Actuation Occur	
4,069	As the Amount of the DHRS Decay Heat Removal Excesses the Core Decay Heat, Plant Cooldown Occurs	

Fig. 1 shows the core power for transient period. At 134.78 seconds, RPS trip actuation signal occurs and core power is abruptly decreased as the insertion of the control assemblies. Fig. 2 shows the temperatures in the core inlet and outlet. At initial time, the core inlet temperaute increases by a failure of heat removal in the affected feedwater pump. After reactor trips, core inlet temperature is gradually increased. The core outlet temperature is abruptly decreased after the insertion of the control assemblies and the temperature increases by the core decay heat. Fig 3 shows core decay heat and DHRS heat removal. After 4,069 seconds, the amount of the DHRS heat removal exceeds the core decay heat. Fig.4 shows the peak assembly outlet temperature. The peak assembly outlet temperature is 591.9 ℃ and it is maintained under the coolant boiling temperature during the transient period.

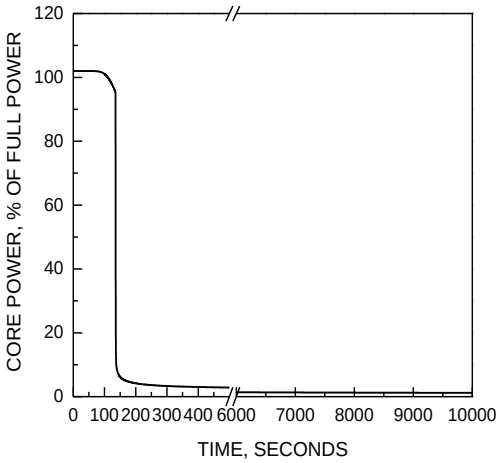

Fig. 1. Core Power

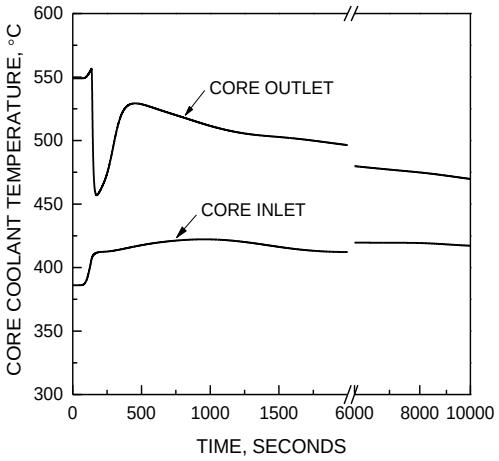

Fig. 2. Core Inlet & Outlet Temperatures

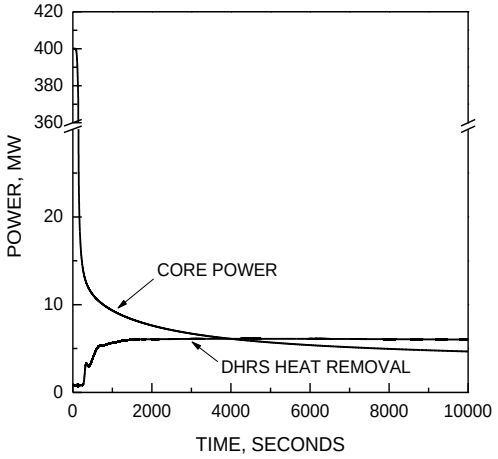

Fig. 3. Core Decay Heat & DHRS Heat Removal

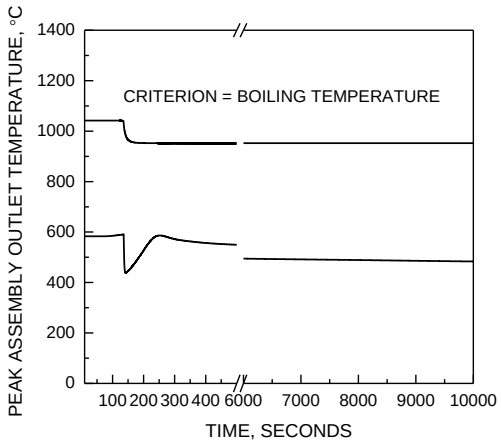

Fig. 4. Peak Assembly Outlet Temperature

4. Conclusions

A safety analysis for single feedwater pump seizure event is carried out using MARS-LMR code. A reactor trips by reaching a core inlet temperature trip setpoint

for single feedwater pump seizure event. During a transient period, the peak outlet coolant temperature is satisfied to a safety acceptance criteria for DBA Class-2.

ACKNOWLEDGEMENT

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