Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-19, 2023

Preliminary safety analysis on 100MWe long fuel cycle sodium-cooled fast reactor under the unprotected loss of single IHTS pump

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1. Introduction

The SALUS(Small, Advanced, Long-cycled and Ultimate Safe sodium-cooled fast reactor)[1] is a 100MWe long fuel cycle sodium-cooled fast reactor system under development in KAERI. The overall system design characteristics of SALUS are similar to those of the 150MWe PGSFR (Prototype Gen-IV Sodium-cooled Fast Reactor) except for the core.

Due to the long fuel cycles, the safety assessment for each cycle is very important. The safety acceptance criteria for SALUS are assumed to be the same as those for PGSFR. CDF(Cumulative Damage Fraction)[2] is an important safety acceptance criteria for AOO and DBA-1 and coolant temperature is that for DBA-2 and DEC conditions[3].

As a first step of the safety analysis on the SALUS, a model-building and a series of the safety analysis on the current design have been started using MARS-LMR code[4]. MARS-LMR code is the modified version of MARS code, which has been supplemented with SFR features including liquid metal heat transfer and additional reactivity feedback models.

In order to find the conservative initial condition, a series of steady state calculations have been performed at the various LCO(Limiting Condition for Operation) for the BOC(Begin Of Cycle) and the EOC(End Of Cycle) fuel conditions.

The transient calculation for the loss of heat sink accidents without reactor scram, ie. unprotected LOHS(Loss Of Heat Sink) accident, has been performed based on the derived conservative initial condition. In this paper the MARS-LMR model for SALUS is introduced and the results related to the sensitivity analysis and the analysis on the unprotected loss of single IHTS pump accidents are presented.

2. MARS-LMR model for SALUS

MARS-LMR model for the analysis of SALUS has been build up. Fig. 1 shows the nodalization of SALUS for ULOHS. The nodalization figure is limited to the PHTS(Primary Heat Transport System) and DHRS(Decay Heat Transport System) due to the limited space available. The core is modeled with 8 channels including driver fuel, control rod, reflector and shield assemblies. SALUS is a pool type reactor with two pumps, four IHXs, and four DHXs. The IHTS(Intermediate Heat Transport System) consists of two loops and the DHRS(Decay Heat Removal System) is composed of two passive trains and two active trains. The two passive trains and two active trains are modeled as single passive train and single active train by preserving the total heat removal capacity, respectively.

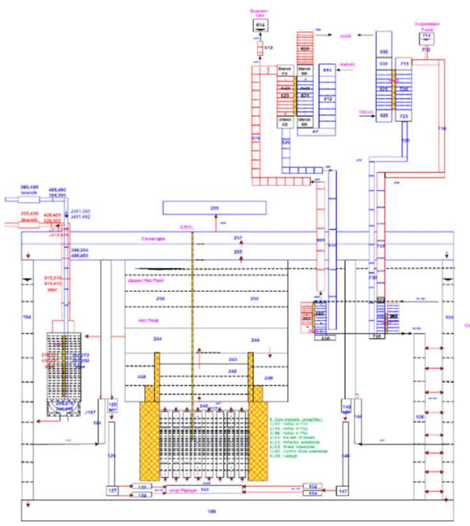

Fig. 1 Nodalization of SALUS for MARS-LMR

3. Results

3.1 Sensitivity Analysis

In order to determine the most conservative initial condition for the analysis, the steady state calculation has been performed for the various LCOs. The parameter considered are core inlet temperature, core outlet temperature and core power at BOC(blue bar) and EOC(red bar). In the sensitivity analysis for BOC and EOC, the ± 4℃ of temperature and ± 2% of power with respect to the nominal value are taken into accounted. In the analysis, the relative sensitivity was compared among

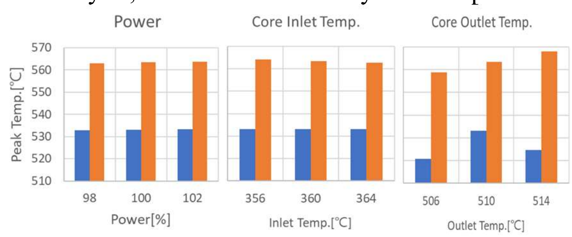

Fig. 2 Effects of variation in power, inlet and outlet temp. at BOC and EOC on coolant peak temp.

the respective parameters, and it was found that the peak coolant temperature varies the most severely with core outlet temperature. The coolant temperature shows the highest peak value at core power of 102%, core inlet temperature of 356℃ and core outlet temperature of 514 ℃ for EOC. These conditions were used as the initial condition of the transient analysis for ULOHS.

3.2 Unprotected Loss of single IHTS Pump Accident

The analysis on the unprotected loss of single IHTS pump accident has been done based on the following assumptions.

It was assumed that the reactor protection systems is unavailable until operator action after single IHTS pumps shutdown due to loss of power or failure, while DPS(Diverse Protection System) is assumed to be available.

After the IHTS pump stops at 10 seconds the flow rate of IHTS loop-1 decreases and the heat removal from the core decreases. However, except for the tripped IHTS pump, the other pumps such as PHTS pumps and feedwater pumps continue to operate, heat removal through the DHRS is maintained, and the reactor trip by DPS does not happen.

Fig.3 shows the flowrate of PHTS and IHTS. The solid symbol represents the information of the tripped loop(IHTS loop-1). As shown in the figure, the flowrate of the whole system except a pump-tripped IHTS loop-1 are maintained. About 10% of normal flow rate through loop-1 is still maintained by natural circulation after accident.

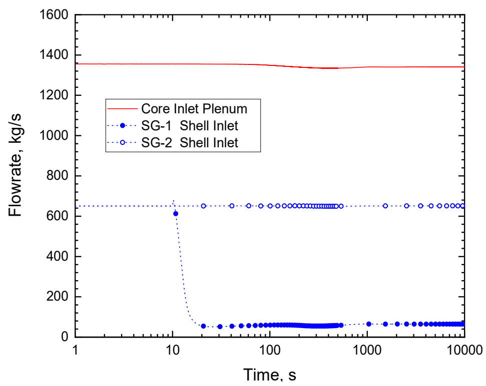

Fig. 3 PHTS and IHTS flowrate

Fig. 4 represents the inlet and outlet temperature variation at core and two IHXs(Intermediate Heat Exchangers). The core inlet temperature increases slowly and actuate the DHRS near 100 seconds and then reaches to 396 ℃. The core outlet temperature shows the peak at 529 ℃ and then converges to 480 ℃. The outlet temperature of the IHX-1 starts to decrease around 400 seconds and reaches to 240 ℃.

Fig. 5 represents the heat balance of SALUS. The heat removal rate through IHTS reduces to around 150 MWt due to the loss of single IHTS flow rate immediately after

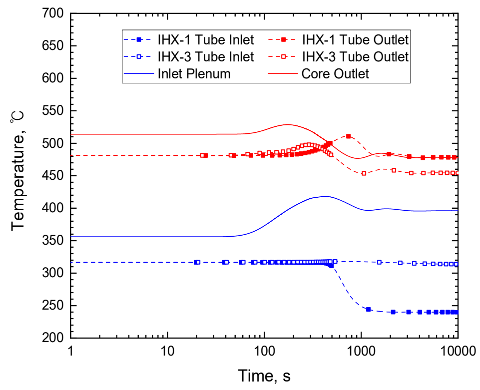

Fig. 4 Temperature variation

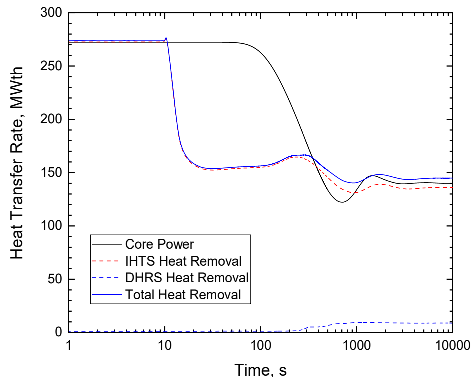

Fig. 5 Heat balance of SALUS

IHTS pump trips, however, core power starts to decrease around 100 seconds due to negative reactivity feedback. The most of heat removal is done through IHTS and the contribution of DHRS is very small.

In order to check the peak coolant temperature, the coolant temperature at respective core channels is presented at Fig. 6. The peak temperature of coolant reaches at 569.4 ℃. at 154 seconds, which is much lower than the sodium boiling temperature(882 ℃), and stabilizes around 500 ℃. It can be confirmed that SALUS under loss of single IHTS pump have enough safety margin.

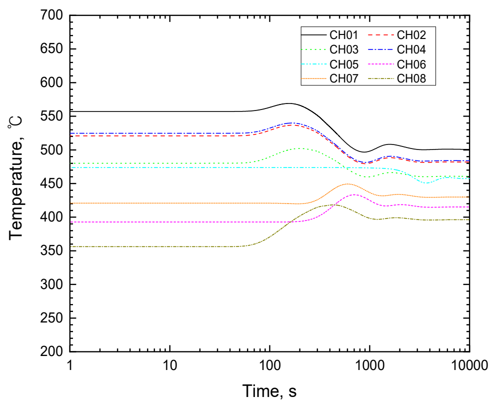

Fig. 6 Coolant temperature at core channel

3. Conclusions

The LCO sensitivity analysis on 100MWe long fuel cycle sodium-cooled fast reactor have been performed for BOC and EOC conditions under loss of single IHTS pump accident. The core exit temperature was found to be the most sensitive parameter to coolant peak temperature among core inlet, outlet and power. The coolant temperature shows the highest peak value at core power of 102%, core inlet temperature of 356℃ and core outlet temperature of 514 ℃ for EOC.

The safety analysis for the conservative conditions shows that the SALUS satisfies the safety acceptance criteria under loss of single IHTS pump accident.

4. Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT). (No. 2021M2E2A1037871).

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