Study on the Verification of Control Logic Code of NSSS for Integral Reactor

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Introduction

Integral Reactor

- The reactor in which major equipment, such as a Core, Steam Generator(SG), Pressurizer, and Reactor Coolant Pump, are placed in a single reactor pressure vessel.
- Unlike a large commercial reactor, there are no large pipes connecting major equipment, so it can eliminate leakage of reactor coolant.
- In addition, the passive safety concept is applied to mitigate accident by natural force in the event of an accident.

Control of NSSS

- Since the core power, amount of coolant, and operation method are different from commercial reactors, a dedicated code is needed to simulate the integrated reactor and evaluate the control logic to determine the control coefficient used in the reactor regulating system and the reactor power cutback system.

※ RRS : Modify core reactivity and control primary temperature using control rod assemblies(CRAs) through CRDMCS

※ RPCS : Generate turbine runback signal and turbine load increase inhibit signal at the accident of loss of feedwater pump or loss of feedwater heater

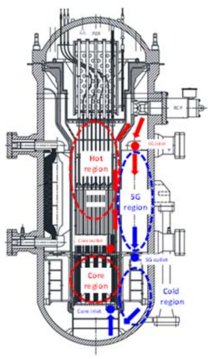
Purpose

- Therefore, in this study, the control logic evaluation code for an integrated reactor was developed, and the results were compared with that of TASS/SMR-S.

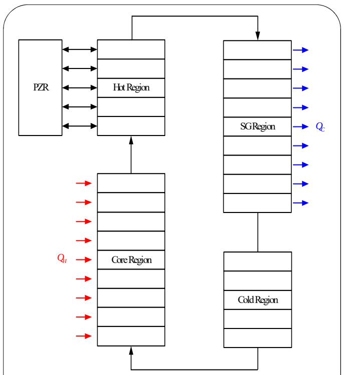
Calculation Methods

Composition of Reactor Coolant System(RCS)

- Flow path : Core – Hot region – SG – Cold region – Core
- Core region : transfer core heat to RCS
- Hot region : heat transfer between reactor coolant and Pressurizer
- SG : heat removal from primary to secondary
- Cold region : no heat transfer, reactor coolant flows from SG to Core



<RCS Flow Path>



<Schematic Diagram of RCS>

Governing Equations

- Continuity Equation

$$\frac{\partial \rho}{\partial t}+\frac{1}{A}\frac{\partial W}{\partial x}=0$$

- Energy Conservation Equation

$$\frac{\partial (\rho i)}{\partial t}+\frac{1}{A}\frac{\partial (Wi)}{\partial x}=\dot{q}'''$$

Assumptions

- One-dimensional flow.
- constant heat flux at core region & SG
- Adiabatic condition in all regions except core and SG regions
- The bypass flow at core and SG regions is ignored

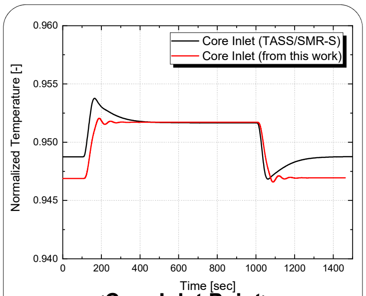
Results

Core region

- Reactor power step change from 100% to 90% at 100 seconds
- The core inlet temperature starts to increase due to this integral reactor design characteristics.
- After reaching steady state condition, the reactor power increased from 90% to 100% at 1000 seconds
- The core inlet temperature starts to decrease, and goes to the steady state temperature.
- The results of the present work simulate that of TASS/SMR-S similarly in trend (red line).
- The temperature differences at steady state condition occurred due to the slightly different volume used in both program
- The time for reaching steady state is estimated shorter than that of TASS-SMR-S. This may caused by the calculation of reactor pressure vessel structure.

SG region

- The SG inlet temperature starts to decrease because of this integral reactor design characteristics.
- The results of the present work simulate that of TASS/SMR-S similarly in trend (red line).
- The temperature differences occurred. However this result seems to be allowable. The time for reaching steady state is still different. This seems to be the thermal mass problem.



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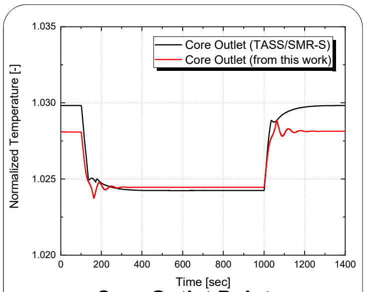

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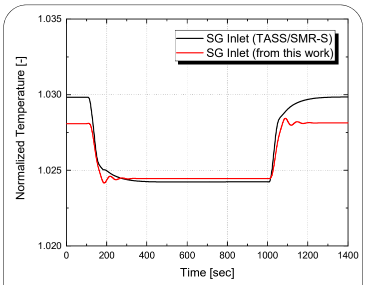

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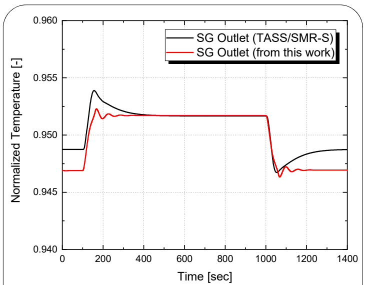

<SG Outlet Point>

Conclusion

- The maximum steady state temperature error : 0.5°C.
- Similar trend with TASS/SMR-S.
- Needed improvements of the program
  - The structure of reactor pressure vessel (thermal mass calculation)
  - SG secondary side calculation
  - Adjust control parameters for reaching steady state