Development of the MMS model for a plant dynamics analysis of a Prototype SFR

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1. Introduction

The MMS model for a prototype SFR plant dynamics analysis has been developed. It includes the modeling of various subsystems like the neutronics, primary and intermediate sodium systems of the NSSS, steam and water of the BOP, BOP controls, and the supervisory plant controls. The NSSS model is subdivided into component models, such as a CORE, IHXs, Pumps, SGs, and the rest of the NSSS loop model. The BOP model is subdivided into a steam subsystem, feedwater subsystem, and preheater subsystem. All of these models have been incorporated into the Master model to simulate transients in the plant, and representative results of the model calculations at a 100% power level are presented.

2. Models and Results

2.1 NSSS Model

The NSSS model is subdivided into component models, such as a CORE, IHXs, Pumps, SGs, and the rest of the NSSS loop model.

The core model consists of five PIPEHX modules, five QMETAL modules, one FUEL module, and one code block. The flow through the core is modeled using two flow paths which mean two average channels. The average channels are modeled using five PIPEHX modules. The PIPEHX module was modified to incorporate sodium properties and the related heat transfer correlations.

The FUEL module of the CORE model calculates the reactor thermal power using the point kinetics model. It has a six-delayed-neutron-group model, three-decay-heat-group model, Iodine-Xenon chain model, temperature dependent Moderator Temperature Coefficient (MTC) and Doppler Coefficient models, and a fixed neutron source model. The control rod reactivity is modeled outside of this model as a Fortran subroutine. The calculated thermal power is distributed into the fuel nodes and connected moderator nodes according to the user-provided fraction of the energy deposition.

The nuclear fuel cladding and moderator are simulated outside this module by separate QMETAL and PIPEHX modules, respectively. Five QMETAL modules represent the cladding material.

The control logic for the core power are programmed in the code block RXCB, which generates control rod insertion/withdrawal signals, and calculates the bank location and rod worth.

There are four IHXs and two SGs in the prototype SFR, but all of them are lumped into one model for simplicity. The IHXs are modeled with five axial control volumes for the PHTS-side, IHTS-side using PIPEHX modules, and the tube metal. The SGs are modeled using the PIPEHX modules. The SG model represents only the active heat transfer part of the once-through steam generator, which corresponds to the steam-water part from just after the tube inlet orifice to the steam outlet of the active tube. The active part is modeled with twenty axial control volumes for the steam-water-side, IHTS-side using PIPEHX modules and the tube metal. The axial tube lengths of the 20 control volumes are equal.

Coolant flows in the hot and cold pools are substituted into the PIPE modules with adequate flow resistance and volumes. The flow path or connecting pipe has volume, mass, and flow resistance.

Figure 1 shows the developed NSSS model. Figure 2 shows the calculation results of the steady-state temperatures of the NSSS Model.

2.2 BOP Model

The major components in the BOP are included in the MMS mode. The BOP model can be broadly subdivided into a steam sub-subsystem, feedwater sub-system, and preheater sub-system. The BOP model also includes an electronic generator. The condenser is treated as boundary conditions. The seawater sub-system will be modeled in future work. The model for the steam sub-system consists of a turbine model and desuperheater model. The condensed feedwater from the condenser goes through the condenser pump, low-pressure preheater, deaerator, the main feedwater pumps, the main feedwater control valve, and two high-pressure preheaters, sequentially. Finally, it enters the steam generators.

The secondary system model for the MMS prototype SFR model is developed using existing MMS RTC modules. The developed secondary system model includes most of the actual prototype SFR secondary system components such as the turbine, preheater, and condenser.

The thermohydraulic characteristics of most components are fixed from the AP form or controlled by the attached control block. The command signals for the valve open/close and pump on/off are supplied from the code block, which describes the high level control logics and operation procedures.

The steam sub-system is filled with steam or two-phase water and includes the components from just after the steam generator to just before the condenser. The model for the steam sub-system consists of a turbine model, desuperheater, and extraction lines for preheaters. The steam just after the steam generator comes into the steam header, and is split into two portions. One of them goes through reheater to reheat the main steam from the high-pressure turbine before it enters the intermediate-pressure turbine. After these components, steam is collected and sent to seven preheater modules to warm up the feedwater.

The steam coming to the turbine system enters the turbine control valve TCV. The turbine control valve actuator, TCA, receives the control signal from the code block, which includes several control logics depending on the overall control mode.

An impulse type turbine module is used for first stage of high-pressure turbine and reaction type turbine modules are used for later stages of the turbines including intermediate-pressure turbines and low-pressure turbines. Each turbine module has two outlet ports. One port is for the flow, and the other for mechanical energy and a turbine speed transfer. Through the latter port, the mechanical energy is delivered to the generator module, which calculates the electronic power and turbine speed. The turbine speed is returned to the turbine using the same port. The turbine modules are type II MMS RTC modules and require junction type modules between them. Splitter modules are inserted between each turbine module. The splitter modules have steam extraction lines into the preheaters.

The condensed feedwater goes through condenser pump, the tube side of the low pressure preheater, the main feed pumps, the feedwater control valve, and the tube side of the high pressure preheaters. Finally, it enters the steam generators.

The preheater sub-system is composed of two high pressure preheaters, a deaerator, and four low-pressure preheaters. Each preheater sub-system includes the preheater itself, the isolation valve, level control valve, dump valve, and code block that describes the special operational procedure.

Figure 3 shows the developed BOP model.

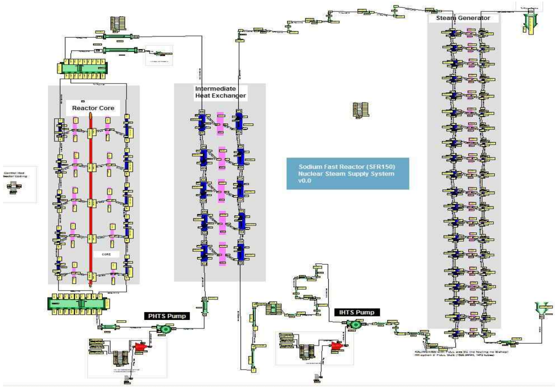

Fig. 1. NSSS model.

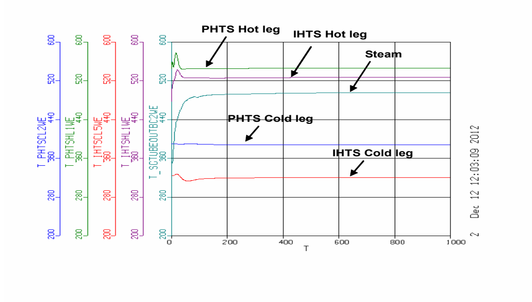

Fig. 2. Steady-state temperatures of NSSS Model.

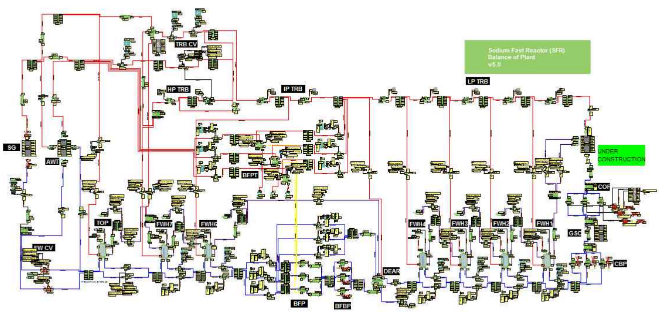

Fig. 3. BOP model.

3. Conclusions

A basic platform using the commercial code, MMS, can be a useful tool for designing a plant operational characteristics. The MMS model for prototype SFR plant dynamics analysis has been developed. This model is useful for developing the plant operation logics of the prototype SFR.

ACKNOWLEDGEMENT

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