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Development of the Reactor Leading Control mode MMS model for Prototype SFR power control

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1. Introduction

Dynamic simulation is necessary to define, design and refine the operation procedure and the process, as well as testing the plant operation under various modes of operation. As a tool for the development of the simulator of the Prototype SFR, the MMS (Modular Modeling System) code [1] was used.

The MMS model for a prototype SFR includes the modeling of various subsystems like the neutronics, primary and intermediate sodium systems of the NSSS, steam and water systems of the BOP, BOP controls, and the supervisory plant controls.

The purpose of this paper is to present the reactor leading control mode model, as well as the results of a transient analysis during power maneuvering according to the power control logic.

2. Models and Results

2.1 NSSS and BOP Models

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

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 model for the steam sub-system consists of a turbine model, desuperheater, and extraction lines for 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.

2.2 Reactor Leading Control Mode Model

The Prototype SFR has an operation mode for a power change, that is, the reactor leading mode to have efficient accommodation of the required plant power and load changes.

In the reactor leading mode, the power set point signal is sent to the primary loop. The reactor adjusts control rods, changing reactivity, which in turn changes reactor power. The remaining plant systems will control to their set points, effectively following the reactor.

The following are steps of the reactor leading mode.

1) Adjust control rods for load. Control rods are inserted or removed to adjust the reactivity in response to load demand. The control rods controller calculates the differences between the actual and target values for reactor power and average core temperature. If the difference exceeds the error band, rods begin moving at a fixed velocity.
2) Primary loop pump control is used to maintain primary side hot leg temperature. The PHTS pump controller generates an overall demand based on the feed-forward flow plus a bias from either the hot leg temperature(normal) or cold leg temperature(over-ride).
3) IHTS loop pump control is used to maintain IHTS cold leg temperature. The IHTS pump controller generates an overall demand based on the feed-forward flow plus a bias from cold leg temperature.
4) A feedwater control valve is used to maintain a constant steam temperature. The FCV controller generates an overall demand from a feedback feed water flow signal. The set point is feed-forward multiplied by a bias as steam temperature controller.
5) A throttle control valve controls the steam pressure.

Some elements must always be controlled. These include the following component parameters.

(1) Turbine Control Valve(TCV) Position
(2) Boiler Feed water Pump(BFP) Speed
(3) Compensate Pump(COP) Speed
(4) Feed-water Heater(FWH) Level
(5) Feed-water Temperature

2.3 Results

In order to verify a reactor leading mode model for Prototype SFR, the model was ramped down from a maximum of 100% power to 75%, 50%, 30% power.

Maneuvering is performed with a demanded load reduction at 2% per minute with a total allotted time of 10000 seconds to stabilize. Figure 1 shows demanded power and actual power. Figure 2 and Figure 3 show the transient results of temperatures and flowrates of PHTS and IHTS. Figure 4 shows the transient results of Steam Pressure and TCV/FCV Positions. It is shown that the transient analysis model can calculate the transient for a power change properly without severe oscillations.

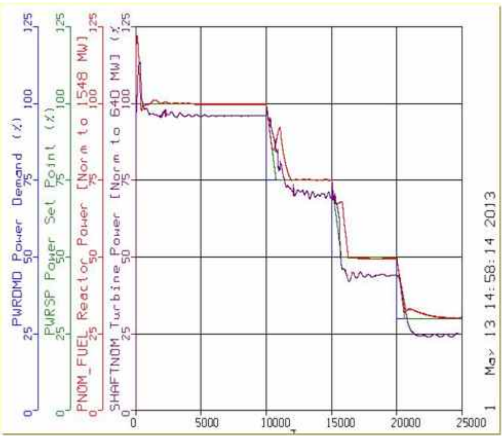

Fig. 1 Demanded and actual powers

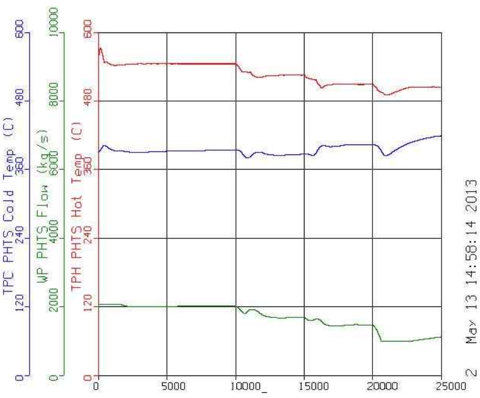

Fig. 2 PHTS Temperatures and flow rate

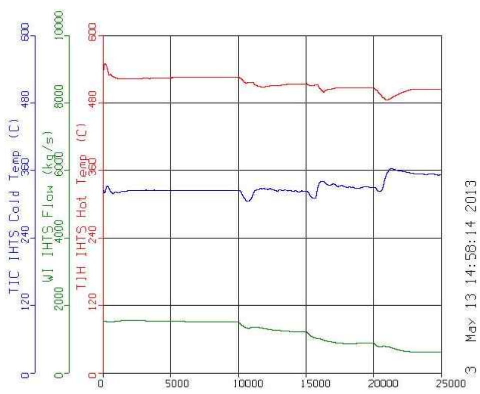

Fig. 3 IHTS Temperatures and flow rate

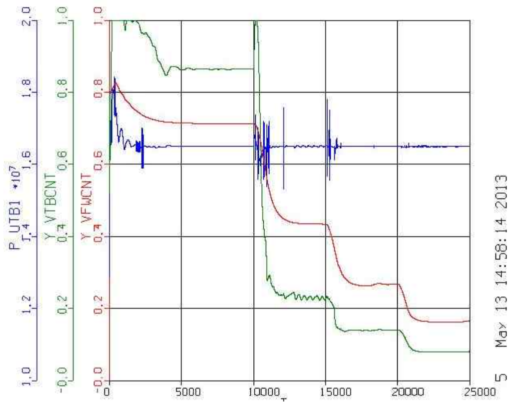

Fig. 4 Steam Pressure and TCV/FCV Positions

Table 1 shows comparison of steady-state results at 100% and 30% with the design data for PHTS and IHTS flows and cold/hot leg temperatures, feedwater flow and inlet/outlet SG temperatures. It shows that error of flow rate and temperatures are within 2% at 100% power, and 2% ~ 5% at 30% power.

Table 1 Comparison to the design data and error at 100% and 30% power

100%	PHTS Flow	TPH	TPC	IHTS Flow	TIH	TIC	Feed water	Feed Temp.	Steam Temp.
MODEL	2028.3	545.1	393.6	1519.3	525.6	324.0	170.7	229.4	499.7
REF	1991.8	544.75	389.76	1515.9	526.75	323.76	170.7	230	503
ERROR (%)	1.8	0.1	1.0	0.2	-0.2	0.1	0.0	-0.3	-0.7
30%	WP	TPH	TPC	WI	TIH	TIC	WF	TFW	TSH
MODEL	1141.7	503.7	420.7	631.3	503.4	351.3	56.3	253.9	502.8
REF	1095.49	503.84	419.31	615.46	503.49	353.34	54.62	259.6	503
ERROR (%)	4.2	0.0	0.3	2.6	0.0	-0.6	3.0	-2.2	0.0

4. Conclusions

The reactor leading control mode model was developed for the simulation of transients and a steady-state operation of the Prototype SFR using the MMS code. A transient analysis during power maneuvering from 100% to 30% power was performed to assess the power change capability of the model. The analysis results show that the reactor leading control model is considered satisfactory for an evaluation of the system performance.

ACKNOWLEDGEMENT

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REFERENCES

[1] nHance, MMS Basics, nHance Technology Inc., 2007.