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Simulation of SMART Startup Operation

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1. Introduction

An advanced integral pressurized water reactor (PWR), SMART (System-integrated Modular Advanced ReacTor) is under development in KAERI [1]. The power level is about 330MWt and it has dual purposes; one is electricity generation, the other is seawater desalination.

SMART is designed as an integral type reactor. That is, the main components, such as the reactor coolant pumps, the steam generators, and the pressurizer, are located in the reactor vessel as shown in Fig. 1.

As the reactor coolant pumps (RCPs) are located in the vessel, the startup procedure of the loop type reactor, heatup of coolant by RCP operation, is very difficult in the SMART. For this reason, the new startup operation by auxiliary heater and nuclear heating is developed in SMART.

In this study, the overview of the startup operation of SMART and the simulation results are presented.

2. SMART Startup Procedure

At first, the coolant is heated up by the RCPs, pressurizer heaters and auxiliary heater to the temperature level where the core critical operation is allowed. This procedure is called auxiliary heatup operation.

After finishing the auxiliary heatup operation, the core critical operation begins. In this operation, the control rod assemblies are withdrawn from the core and/or the boron concentration is regulated by operator to make the core critical.

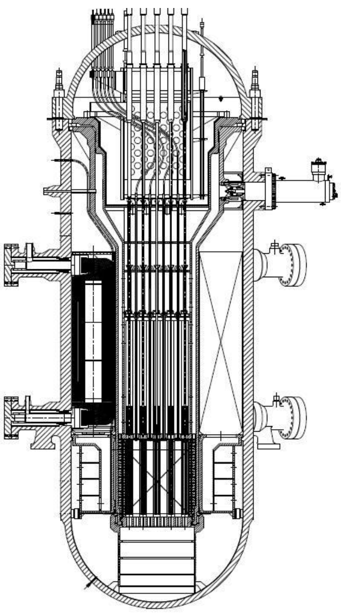

Fig. 1. The Layout of SMART

When the core becomes critical, the coolant can be heated up by the nuclear power; the energy unbalance between the heat production in the primary side and the heat removed by the secondary side.

During the heatup operation, the secondary coolant is circulated by the startup recirculation system as depiected in Fig. 2. This system is adopted to minimize the heat transfer from the primary side to the secondary side.

At the early stage of heatup, the pressurizer reaches saturation condition and the steam space is formed in the upper region to prohibit the system from being operated at the solid state.

As the heatup process goes on, the steam is produced in the outlet region of the steam generator secondary side. This steam is transferred to the condenser through the turbine bypass system until the steam pressure reaches the target value, where the turbine can be operated.

The heating rate in the heatup operation is regulated by operator. To control the heatup rate, the core power is controlled manually. When the secondary side of the steam generator is filled with subcooled water, relatively low power required for heat up the primary coolant, but as the steam is produced in the steam generator; large amount of heat is transferred to the secondary side. So the core power should be increased to maintain the heatup rate.

In the heatup operation, the pressure and level of the

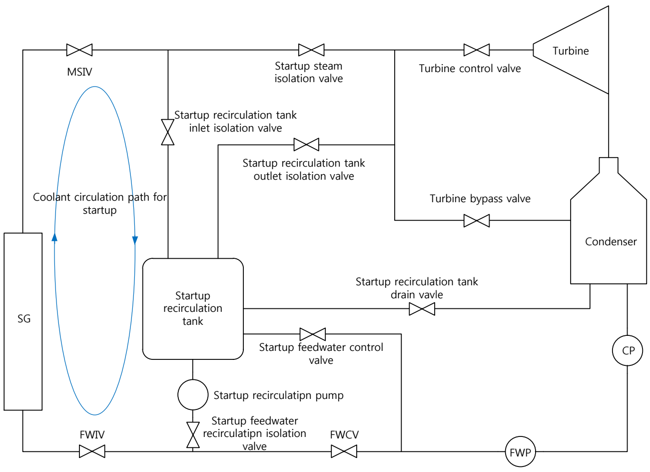

Fig. 2. Simple Diagram of SMART Secondary System

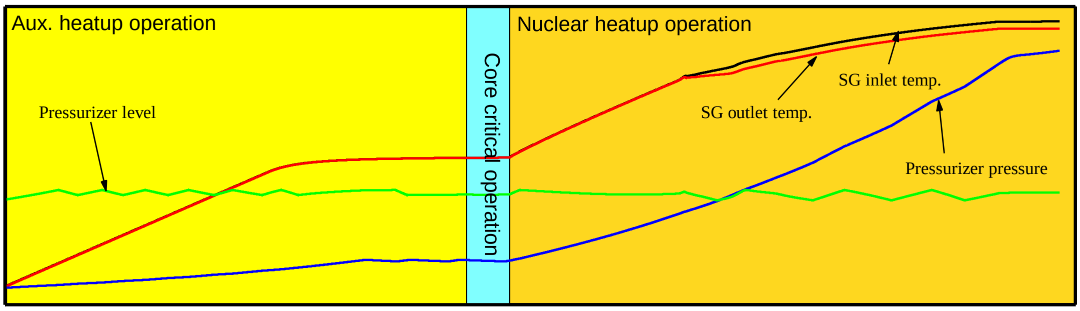

Fig. 3 Simulation of the startup operation of the SMART: Coolant temperature, Pressurizer pressure and level

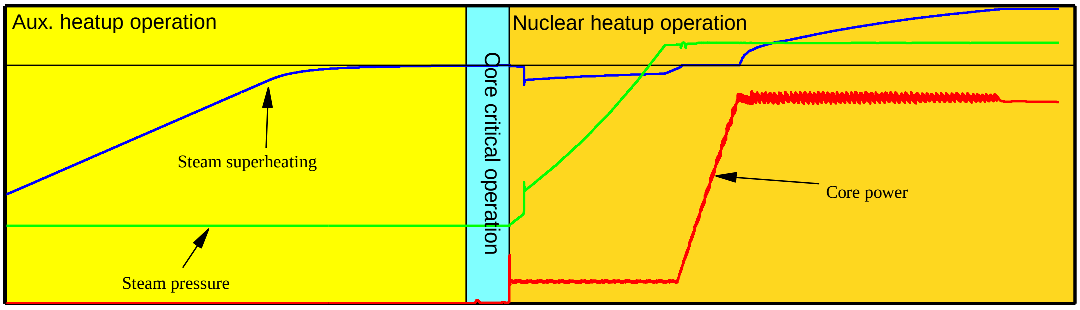

Fig. 4 Simulation of the startup operation of the SMART: Core power, secondary steam pressure and superheating

pressurizer are controlled by the operator manually using the chemical and volume control system (CVCS).

When the primary coolant temperature reaches the normal operating temperature and the secondary steam is produced with enough superheating in the constant pressure, the startup recirculation system is closed and the startup steam isolation valve is opened.

Then the steam starts to flow through the main steam line. Finally, the turbine is actuated by opening the turbine control valve. The turbine bypass system is closed and the main control systems such as the reactor regulating system (RRS), pressurizer pressure control system (PPCS) are set to the automatic mode.

If the core power is stabilized and the main operating parameters are in steady state, the startup operation can be said to be accomplished.

3. Analysis of the Startup Operation

The startup operation of the SMART is simulated with the TASS/SMR-S [2], the one dimensional thermal hydraulic system analysis code. This code is developed in KAERI for the safety and performance analysis of the integral reactor.

The results are shown in the Fig. 3 and Fig. 4. The RCS coolant temperature increases from the beginning of the aux. heatup operation. When the temperature reaches target value, the flow from the aux. heater power is reduced to maintain the temperature. The pressure of the pressurizer also increased to a certain plateau and maintained. No power is produced in the core as shown in the Fig. 4. Therefore the secondary coolant flowing from the steam generator is in the subcooled state.

In the core critical operation mode, there are no significant changes in the thermal hydraulic parameters.

After core critical operation, the nuclear heatup operation begins. In the early state of this operation, relatively small power can increase the RCS coolant temperature steadily as shown in the Fig. 3. When the core power is increased, the superheated steam begins to be produced. The heatup rate is somewhat decreased due to the large heat removal to the secondary side. In the nuclear heatup operation, the steam pressure is controlled to be increased to the target value and maintained at that value. The pressurizer level is controlled to be maintained at constant level throughout the strartup operation.

Finally, at the end of the nuclear heatup operation, the major operational parameters reach the desired value and stabilized.

3. Conclusions

Simulation of the SMART startup operation has been accomplished. The heatup operation with a sequence of aux. heatup and nuclear heatup, different from the conventional reactor, show the required performance. As a future study, the optimization of the operation procedures is required.

REFERENCES

[1] M. H. Chang, S. K. Sim, and D. J. Lee, F. W, SMART Behavior Under Over-Pressurizing Accident Conditions, Nuclear Engineering and Design, Vol.199, p.187, 2000.

[2] Y. C. Chung, et. al., TASS/SMR Code Topical Report for SMART Plant, KAERI/TR-3640/2008, 2008.