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Sensitivity Analysis of Reactor Regulating System for SMART

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1. Introduction

The integral reactor technology is one of the Small and Medium sized Reactor (SMR) which has recently come into a spotlight due to its suitability for various fields. SMART (System integrated Modular Advanced ReacTor), a small sized integral type PWR with a rated thermal power of 330MWt is one of the advanced SMR. SMART developed by the Korea Atomic Energy Research Institute (KAERI), has a capacity to provide 40,000 m3 per day of potable water and 90 MW of electricity (Chang et al., 2000). Figure 1 shows the SMART which adopts a sensible mixture of new innovative design features and proven technologies aimed at achieving highly enhanced safety and improved economics. Design features contributing to a safety enhancement are basically inherent safety improving features and passive safety features. Fundamental thermal-hydraulic experiments were carried out during the design concepts development to assure the fundamental behavior of major concepts of the SMART systems. A TASS/SMR is a suitable code for accident and performance analyses of SMART.

In this paper, we proposed a new power control logic for stable operating outputs of Reactor Regulating System (RRS) of SMART. We analyzed the sensitivity of operating parameter for various operating conditions.

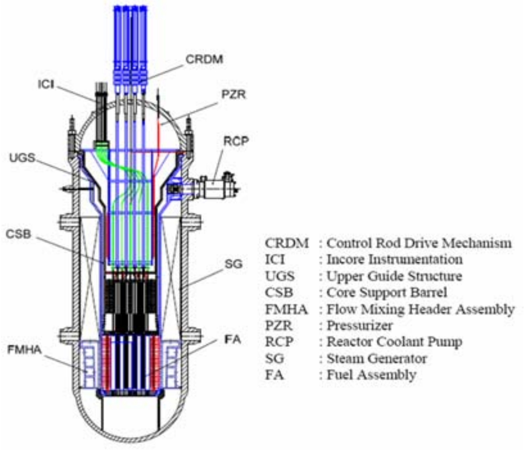

Fig. 1. SMART Reactor

2. Power Control Logic

2.1 Power Control Logic

The turbine-following control logic has been traditionally utilized for the power operation mode of existing PWR plants. The steam generator of the SMART is a once through type. The feedwater leading control logic where reactor power is proportionate to feedwater is applied to SMART RRS. The proposed power control system generates the CRDM insertion/withdrawal signals to match the measured reactor power and steam generator (SG) coolant inlet temperature with reference values. Figure 2 shows the power control logic applied to the SMART. This reference temperature is based on feedwater. The temperature deviation signal was amplified through the lead/lag filter, and a control rod is operated by a little difference of temperature. An allowable error of average temperature and reference temperature is ±1.5°C.

We used a power deviation signal with a differential filter. The filter is very sensitive to the rate of power variation. An allowable error of rated reactor power and feedwater flow rate is ±2%.

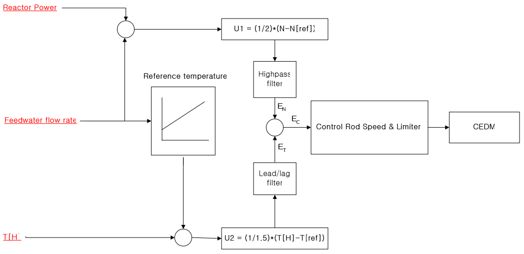

Fig. 2. Power Control Logic Diagram

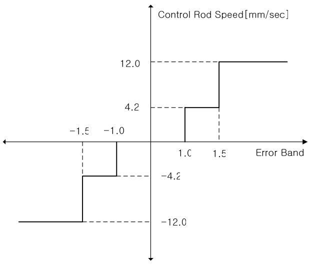

Fig. 3. Control Rod Speed Program.

2.2 Control Rod Speed Program

The sum of the power deviation signal value and the temperature deviation signal value decide the speed and direction of the control rod through a control rod speed program in figure 3. If the sum of absolute value is bigger than 1.0, the control rod speed program sends a signal to a CRDMCS. If the value of the sum of deviation signal is between ±1.0 and ±1.5, the control rod will move at ±4.2mm/sec rate. And if the sum of deviation signal is above the ±1.5, the control rod will move at ±12.0mm/sec rate. The control rod will be inserted if E_C is bigger than 1.0, and, conversely the control rod will be withdrawn, if the sum of deviation signal is smaller than -1.0. The control rod will be stopped if the sum of deviation signal is 0.

3. Simulation and Results

3.1 100%-90% Step Load Decrease

The figure 4 shows the reactor power of the 100%-90% step load decrease scenario. The control rod moved at 4.2mm/sec rate for 10-20 seconds. If the core power is stabilized, the control rod will no longer move. As a result, there was temperature difference 0.779° C and core power difference 0.0117%.

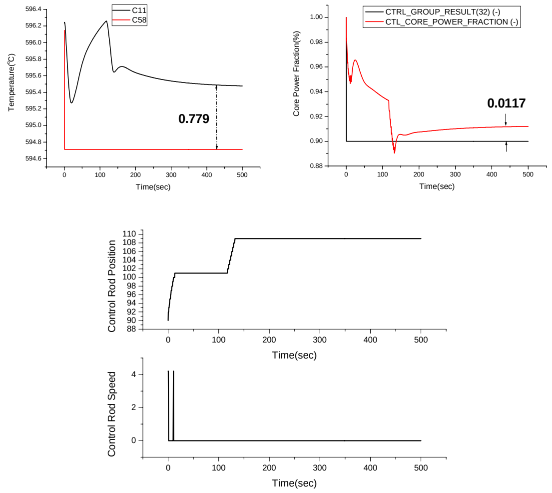

Fig. 4. 100%-90% Step Load Decrease

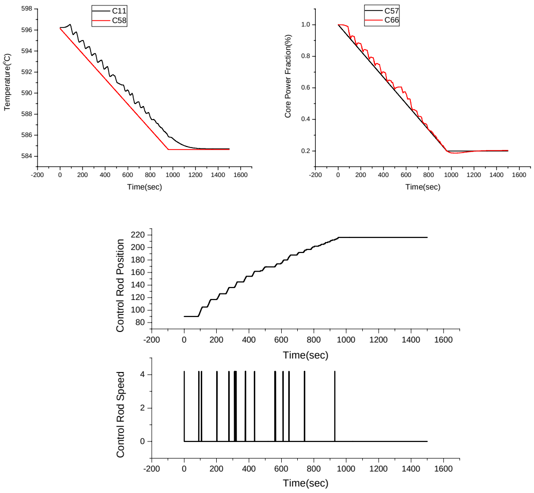

Fig. 5. 100%-20% Ramp Decrease at 5%/Min

3.2 100%-20% Ramp Decrease at 5%/Min

The figure 5 shows the reactor power of the 100%-20% ramp decrease at 5%/min rate scenario. The control rod moved at 4.2mm/sec rate for 920-930 seconds. If the core power is stabilized, the control rod will no longer move. The temperature and the core power is stabilized which takes about 1200 seconds.

3.3 100%-65% Ramp Decrease at 10%/Sec

The Fig 6 shows the reactor power of 100%-65% ramp decrease at 10%/Sec rate scenario. The control rod moved at 4.2mm/sec and 12.0mm/sec rate for 120 seconds. There was temperature difference 1.0508° C and core power difference 0.0136%.

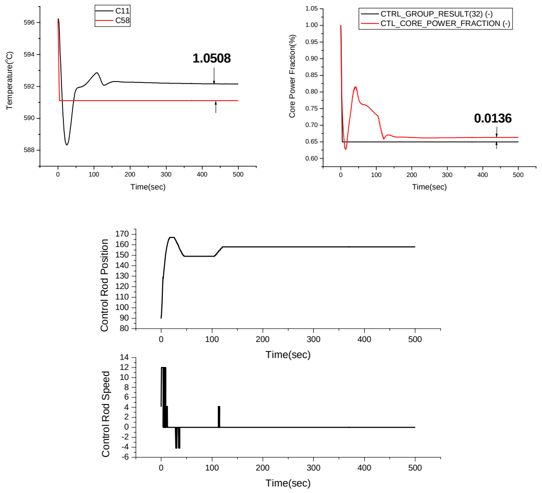

Fig. 6. 100%-65% Ramp Decrease at 10%/Sec

4. Conclusions

We performed sensitivity analysis of RRS for SMART, and the core power was stabilized by using the control rod speed program from the TASS/SMR code.

In the future, a various filter coefficient and optimal control rod movements will be designed, and the applicability of PID controller will be studied.

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