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Power Control Logic Evaluation of RRS for SMART

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1. Introduction

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 reactor. 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 operational scenarios using TASS/SMR.

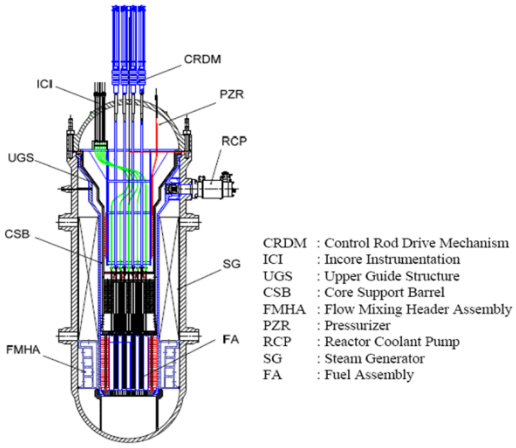

Fig. 1. SMART Reactor

2. Reactor Regulating System

RRS generates signals to change the speed and the position of control rods CRDM(Control Rod Drive Mechanism).

2.1 Power Control Logic

The turbine-following control logic has been traditionally utilized for the power operation mode of existing PWR plants. The helical steam generator of the SMART is a once-through type. The feedwater leading control logic where reactor power is proportionate to feedwater flow rate is applied to SMART RRS.

The proposed power control system generates the control rods insertion/withdrawal signals to match the calculated power and steam generator coolant inlet temperature with reference values. Figure 2 shows the power control logic applied to the SMART. The reference temperature is based on feedwater and reactor power. The derivation signal of hot leg temperature of primary was controlled through the PID(Proportional Integral Derivative) controller, and a control rod is operated by a little difference. It is important to design filters that can catch the error quickly. The PID filter is highly coupled with reactivity compensation. An allowable error of hot leg temperature and reference temperature is ±1.5°C.

We used the power deviation signal with a derivative 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%.

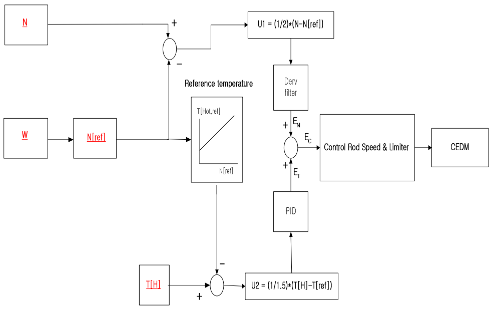

Fig. 2. Power Control Logic Diagram

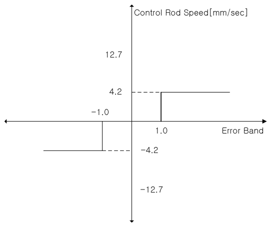

Fig. 3. Control Rod Speed Program.

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(Control Rod Drive Mechanism Control System). If the value of the sum of deviation signal is above ±1.0, the control rod will move at ±4.2mm/sec rate. The control rod will be inserted if E_C is bigger than 1.0, 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 Change

The figure 4 shows the reactor power of the 100%-90% step load change scenario. The control rod moved between 18 and 40 seconds at 4.2mm/sec rate. If the core power is stabilized, the control rod no longer moves. The calculated power overshoot was 0.76%. The steady state error is about 1.1%. As a result, the calculated values follow the reference value well with less control rod movement. The calculation showed that operational variables are within the allowable error band.

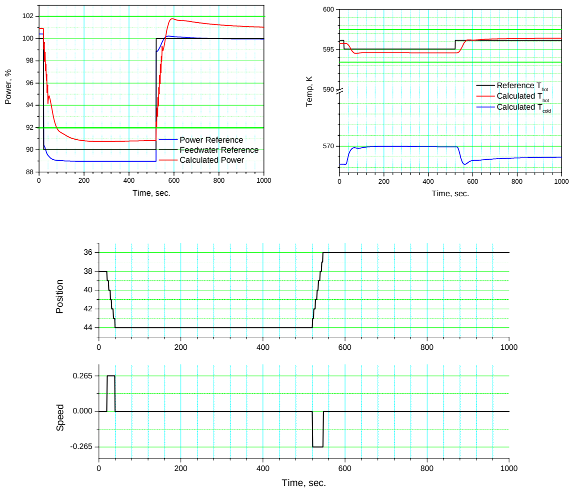

Fig. 4. 100%-90% Step Load Change

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

The figure 5 shows the reactor power of the 100%-20% ramp change at 5%/min rate scenario, which is one of the normal operations. The control rod moved only twice at 4.2mm/sec rate. If the core power is stabilized, the control rod will no longer move. As a result, the calculated values follow the reference value well with minimized control rod movement

3.3 100%-55% Ramp Change at 10%/Sec

The Fig 6 shows the reactor power of 100%-55% ramp change at 10%/sec rate scenario. The control rod moved between 20 and 190 seconds at 4.2mm/sec rate. The steady state error is about 1.8%. The calculated variables need longer stabilizing time with some fluctuating trends. However considering this scenario is the abnormal event, the results is thought to be acceptable.

4. Conclusions

We performed sensitivity analysis of RRS for SMART using TASS/SMR. The results showed that the core power was stabilized by using the control rod speed program and with PID controller for the cases of the load-following operations and the emergency power reducing event.

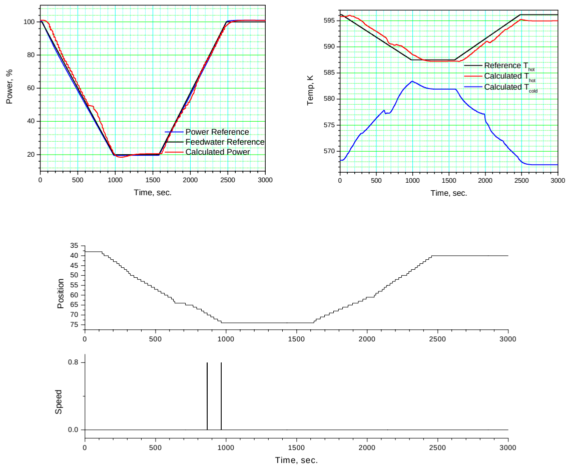

Fig. 5. 100%-20% Ramp Change at 5%/Min

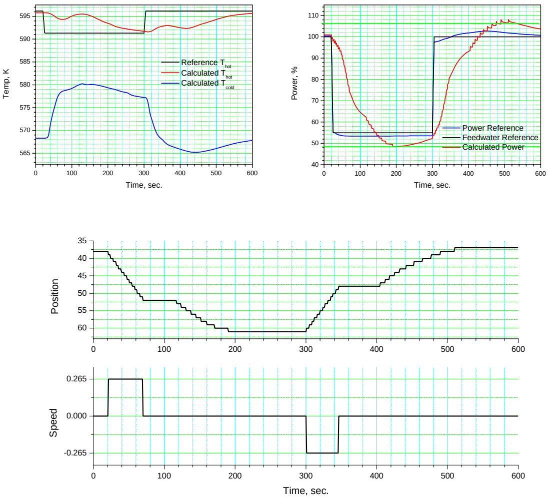

Fig. 6. 100%-55% Ramp change at 10%/Sec

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