Preliminary Performance Estimation of the PPCS of SMART

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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 of this reactor is about 330MWt and 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 all located in the reactor vessel as shown in Fig. 1.

Due to the design differences between SMART and the conventional loop type reactor, the phenomena occurring in the normal operation or the accident condition may be also different. That is, the similar control system to the conventional reactor may show rather different performance in SMART compared to the conventional reactor.

Therefore, in this study, one of the control systems, the pressurizer pressure control system (PPCS) which is introduced for the pressure control of the primary side of SMART is preliminarily analyzed and its performance is estimated for the normal power operation.

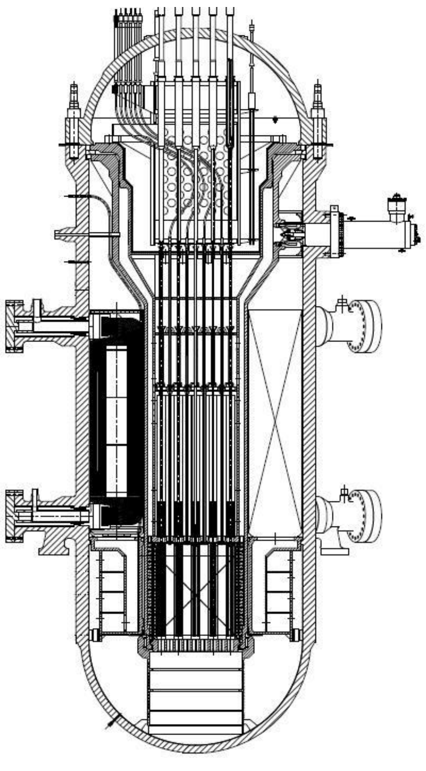

Fig. 1 The Layout of SMART

2. PPCS of SMART

The pressurizer of SMART is defined as the space between upper guide structure upper support plate and vessel head as shown in Fig. 1. The heaters for the pressure control and the spray system for maintaining the boron concentration are positioned in the pressurizer. The pressure is determined by the amount of steam.

There are two types of heater; one is proportional heater and the other is backup heater, similar to the ones of the conventional reactor. The heat from the proportional hater is changed according to the pressure, that is, when the pressure increases, the heat from the heater is reduced, and when the pressure decreases, more heat is added to the coolant to produce more steam. The backup heater, having larger capacity than the proportional heater has only ON-OFF logic for pressure control. If the pressure reaches lower prescribed value, the heater is turned on, and if the pressure rises to a certain value, the heater goes off.

The main spray is not used for the pressure control. It is prepared for maintaining the boron concentration of the pressurizer.

3. Performance estimation of the PPCS

The safety and performance analyses of the SMART are accomplished by the TASS/SMR-S code [2], the one dimensional system analysis thermal-hydraulic code, which is developed in KAERI for integral reactor. The modeling of SMART for TASS/SMR-S code analysis is shown in Fig. 2.

The pressure behavior of the pressurizer can be figured out by the system transient analysis. The power maneuvering operations are considered in this study. One is power step change and the other is power ramping change. The power step change operation is the simulation of the turbine load change. The 10% power change (step up and step down) is assumed in this study. The power ramping change operation is to simulate daily load change. 5%/min. of power decrease/increase operation (from 100% to 20%) is assumed.

In the simulation, the reference power input is given to the reactor regulating system (RRS). Then the core power begins to change according to the power control logics implemented in the RRS. As the power level changes, the system thermal hydraulic conditions deviate from steady state. But the system transient can be minimized with the aids of the control systems. The PPCS is in operation for the pressure control of the pressurizer.

The analyses results are shown in Fig. 3 and Fig. 4 compared with the cases of no PPCS actuation.

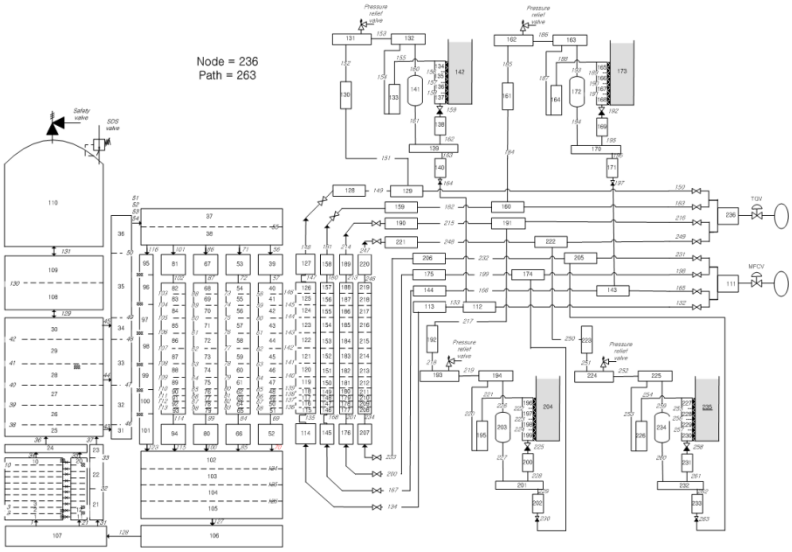

Fig. 2 Modeling of SMART for TASS/SMR-S analysis

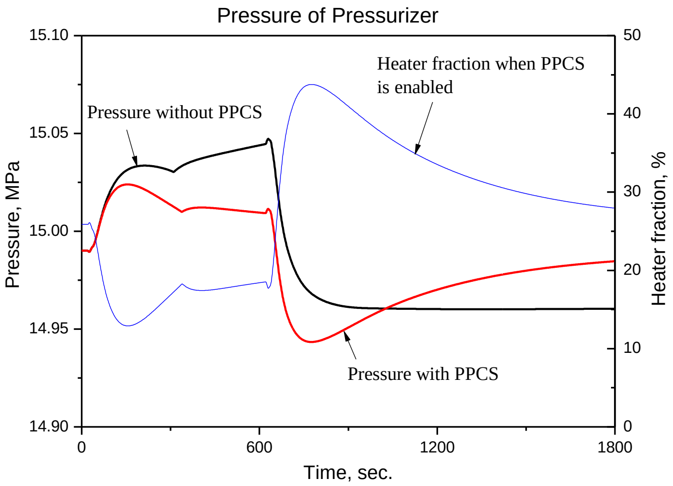

Fig. 3 PPCS performance for power step change

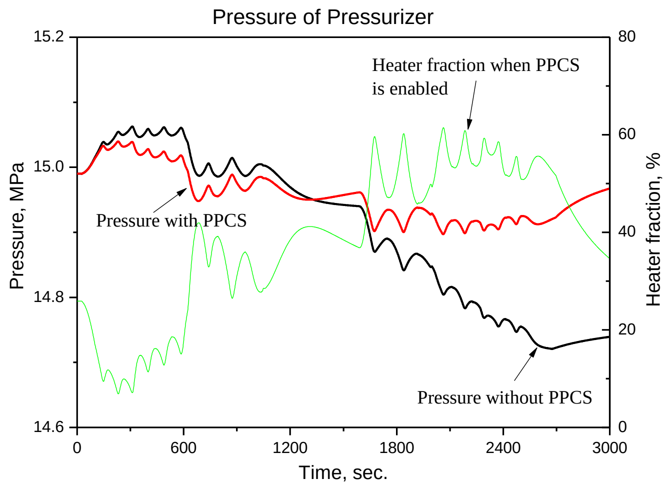

Fig. 4 PPCS performance for power ramp change

The initial pressure of the pressurizer is calculated from the steady state calculation. The PPCS is on both of the cases in the steady state calculation to match the initial conditions.

In the figures, the pressure of the pressurizer and the proportional heater fractions are displayed. The heater fraction means the fractional capacity of the proportional heater compared to the maximum capacity.

As shown in the figures, the maximum pressure and the pressure deviation are reduced by the actuation of the PPCS. That is, if the pressure increases from the nominal value, the capacity of the proportional heater is reduced to limit and reduce the pressure. On the other hand, the heater capacity will be increased if the pressure decreases below nominal value.

For the power step change case, the relative value of the maximum pressure deviation from nominal value is reduced about 50% compared to the case of no PPCS. For the power ramping case, the maximum pressure is slightly reduced but the deviation of the minimum pressure from nominal value is reduced to about 30% of the no PPCS case.

With the aids of the PPCS, the RCS pressure deviation from nominal value can be reduced during the plant transient operation. Therefore more operator action margin can be obtained.

4. Conclusions and Recommendations

The pressurizer pressure control system for SMART is introduced and the preliminary performances have been estimated. The results show the improvement of the pressure behavior in the normal power operation cases.

As future works, more severe cases such as the reactor emergency trip or power setback operation can be analyzed for the estimation of the PPCS performance.

REFERENCES

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