Feed and Bleed Operation Analysis during Total Loss of Feedwater Accident for Supporting the PSA of APR+

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1. Introduction

The Advanced Power Reactor Plus (APR+), which is a GEN III+ reactor based on the proven APR1400, is being developed in Korea and standard design approval is in processing. To enhance the safety of the APR+, a passive auxiliary feedwater system (PAFS) has been adopted for passive secondary cooling. For estimating the safety of APR+ design, the probabilistic safety assessment (PSA) is performed[1]. This paper discusses the minimum success criteria for successful feed and bleed procedure verified and decided when the secondary cooling is failed during Total loss of feedwater (TLOFW) accident.

2. Operation Analysis

2.1 Code Model for Analysis

APR+ plant is modeled by using the best estimate thermal-hydraulic code, RELAP5/.MOD3.3 for a realistic analysis [2]. Fig. 1 shows the noding diagrams of the APR+ and the PAFS.

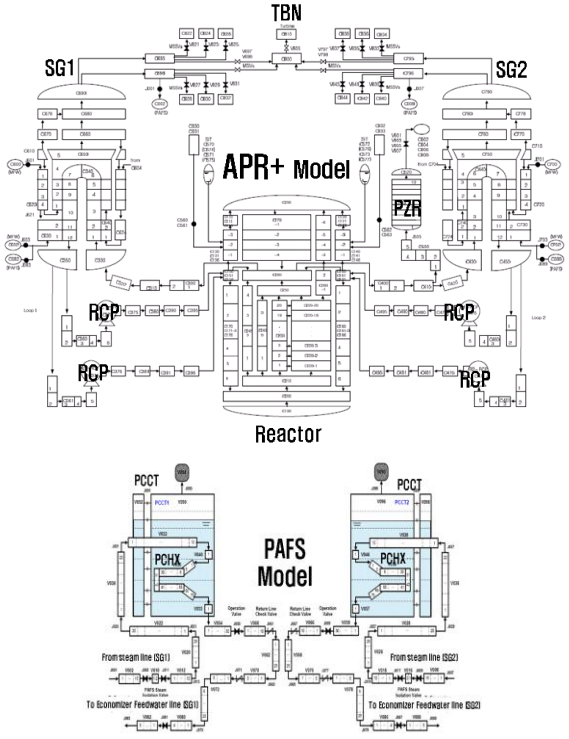

Fig. 1. Noding diagrams of APR+ and PAFS

The RELAP input model of APR+ describes the reactor coolant system with safety injection system and the important parts of the secondary system as main feed water system and PAFS to turbine control system. All essential control and protection systems are modeled for transient analysis. The model is developed in accordance with the design data and system configuration of the APR+ and the PAFS and the PAFS model is attached to the APR+ model. It was assumed that primary heat load is transferred to secondary side. The steady-state analysis is performed by using APR+ condition successfully.

2.2 Test scenarios

The minimum required equipment for successful early F&B managing during LOFW accident is decided from APR+ PSA [3].

- At least two out of four POSRV are opened within 50 minutes after secondary cooling failure for the RCS depressurization
- At least two out of four HPSI pumps has to start for F&B procedure

For accurate APR+ PSA evaluation, the required equipments for F&B procedure were assumed as one POSRV and HPSI pump for F&B procedure [4]. The sensitivity test was performed to verify whether the equipment conditions proposed is enough to manage the transient event without core damage and to decide the maximum available time to start the operator's action under the given accident condition [5].

For analysis, the transient scenarios and assumptions are as follows:

1. Initial event
   - Total loss of feedwater accident
2. System conditions
   - 1 high pressure safety injection pump is available.
   - 4 safety injection tanks, 4 main feed water pumps and 2 PAFS's are unavailable.
   - Without LOOP
3. Operator action
   - 1 pilot operated safety release valve (POSRV) manually open in 60~90 minutes by operator after POSRV's open first.

2.3 Results

The analysis was performed to verify whether the RCS could be cool down without core damage under

the given equipments and decide the timing of the operator's action for feed and bleed procedure. After LOFW accident, the reactor trip is caused by steam generator's low level signal. The RCS could be cooled down by the secondary feedwater and steam removal from main steam safety valves. But when the secondary cooling is failed, the decay heat could be removed by feed and bleed operation using the POSRVs and HPSIs.

As considering the unavailability of all secondary systems, the RCS pressure and temperature start to increase. The pressurizer's pressure reaches at the setpoint pressure for opening of POSRVs. Since the RCS pressure is higher than the shut-off head of HPSI pumps during this transient phase, the primary coolant loss through the POSRVs can be not compensated by the HPSI inflow. To prevent the inadequate condition, the operator should open the POSRVs shortly. For evaluating the maximum available time to start the operation under the given accident condition, the operator opens one POSRV at 60~90 minutes after first opening of POSRVs. As the RCS pressure decrease below the HPSI shut-off head after the operator's action, the cooling water by HPSI is injected to the RCS. The core water levels are recovered by HPSI flow and the RCS pressure could be decreased without core damage by F&B procedures in 80minutes as Fig. 1 and 2.

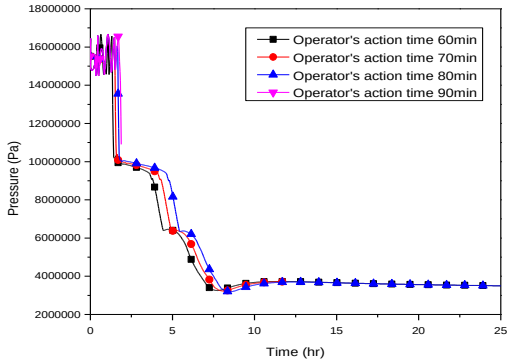

Fig. 1. RCS pressure according to operator's action time (LOFW)

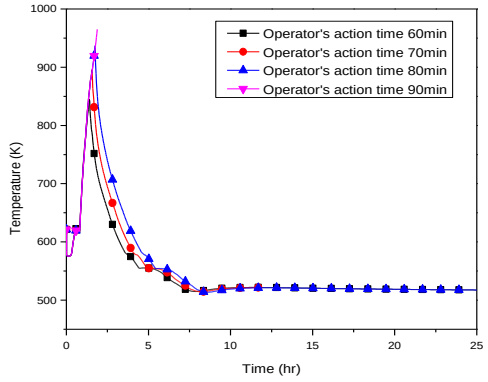

Fig. 2. PCT according to operator's action time (LOFW)

3. Conclusions

For verifying whether the equipment conditions proposed is enough to manage the transient event without core damage, the analysis is performed by RELAP5/MOD 3.3 code.

During TLOFW event, the operator's action time is allowed for 80 minutes and the uncovered core could maintain the stable state for a long time, about a half or one hour by the positive effects given by the fast coolant circulation by RCP pump operation. In simulations considering test scenarios, the minimum required equipment for successful F&B managing during TLOFW without LOOP is verified that it is that F&B procedure could be performed successfully as if the operator would open at least one out of four POSRV within 80 minutes after secondary cooling failure for the RCS depressurization. These analysis results can be used for contribute more realistic and accurate performance of a APR+ PSA.

Acknowledgements

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