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Optimized Operator Action Time Evaluation using the Nuclear Plant Analyzer

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1. Introduction

The new operational procedures need to reflect the changes of power operation at the up-rated plant conditions. In this case, utilities are needed re-evaluation of the current operation procedures with respect to the safety analysis.

For example, because the Loss of Coolant Loss Accident(LOCA) during power operation causes the most severe accident, the safety analysis has been performed in consideration of this accident until now. However, it is widely understood that the specific accident during the plant shutdown can cause the more severe results because the safety systems cannot be operated during the hot standby operation. If the procedure describes that the manual action be completed in 10 minutes, it surely is burden for the operator. On the other hand, if the operator action time is 30 minutes or more, the burden for operator can be alleviated.

To determine the time for the operator action, the results of accident analyses becomes the important factors. The most important acceptable criterion for LOCA is the fuel cladding peak temperature which should be below 2,200°F. Therefore, the operator should startup the Emergency Core Cooling System (ECCS) pump and maintain/recover the RCS inventory before the PCT reaches up to the 2,200°F. Operator action time(OAT) is the interval from the occurrence of LOCA to the fuel clad temperature's change up to the 2,200°F. This paper describes the new evaluation method of the OAT by the thermal-hydraulic analysis using the optimized NPA (Nuclear Plant Analyzer) code in the case of LOCA.

2. Conditions for LOCA Analysis in Mode-3

The following operational mode-3 is prepared for the LOCA analysis by NPA to maintain the hot standby mode through the control of charging, runoff, spray and heater of a pressurizer. The break location is the Loop 1 RCP discharge leg and the size is 4 inch each. In this study, the time for the operator action is evaluated with NPA for the 2,775 megawatts-thermal power in the hot standby operation (Mode-3).

3. Evaluation results of Operator Action Time

The residual heat only is produced after the reactor is shutdowned. The break occurs at the pressurized condition after 0 sec of the shutdown. Figure 1 shows the pressurizer pressure. The pressure suddenly drops and it shows the typical pressure behavior similar to the small-LOCA. Figure 2 shows the pressurizer level. It is also reduced rapidly after a few seconds (10 sec) of the break.

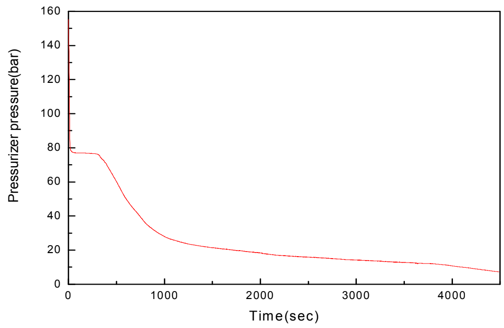

Fig. 1 Pressurizer Pressure

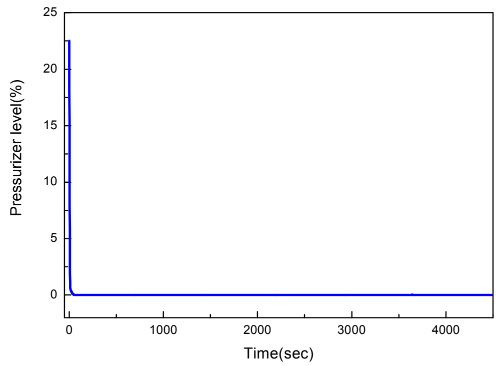

Fig. 2 Pressurizer Level

Figure 3 shows the temperature of the reactor coolant system (RCS) cold leg. The hot water in the RCS is mixed with the cold water injected from the accumulator from 700 sec to 3,650 sec. After 3,600 sec, the temperature of the RCS cold leg becomes stable because of the emptied accumulator. From 700 sec to 3,650 sec, the temperature changes in the Loop 1 are different from those of the Loop 2 since the break is assumed in the Loop 1 and the injected water from the accumulator through the Loop 1 is interacted relatively less than that of the loop 2. It also shows that the temperature is maintained to the saturation temperature of the RCS pressure. Figure 4 shows the flow rate in the broken pipe. The critical flow rate is maintained at the moment that the break occurs. However, the water in the down-comer is continuously discharged to the containment by the pressure difference until the RCS pressure becomes low enough.

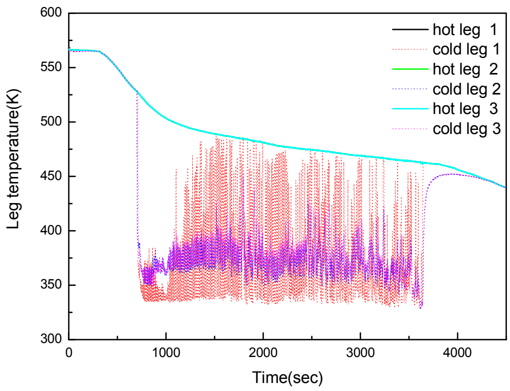

Fig. 3 Cold leg and hot leg temperature in RCS

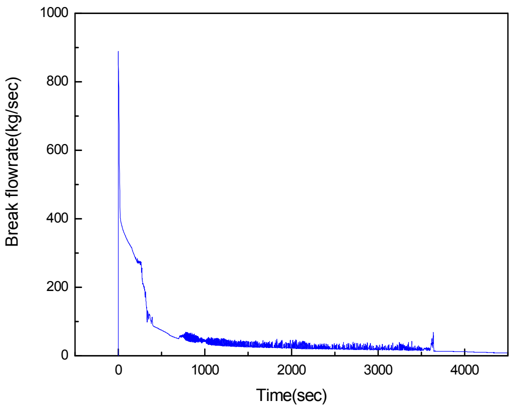

Fig. 4 Flow rate in broken cold leg

Figure 5 shows the injected flow-rate from the accumulator to the RCS. As described above, the ECC water is injected from 700 sec to 3,650 sec by the pressure difference between the accumulator and RCS and the accumulator is emptied out around 3,650 sec.

Figure 6 shows the fuel clad temperature. It is maintained to the saturation temperature of the given RCS pressure until 1,700 sec. From 1,700 sec after the break, the core begins to boil out and the clad temperature in the active fuel top begins to increase. This temperature increase is progressed continuously and propagated to the center of the core, and eventually the fuel clad temperature at the fuel top exceeds 2,200°F at 4,500 sec. At this time, the analyses are finished.

As shown in Figure 6, the operators' time margin is 2,000 sec (33 minute) because the acceptable criterion dose not exceeded between 0 sec and 2,000 sec. Therefore, the operator can manipulate the isolated high pressure safety injection pump and inject the ECC water within 33 minute after the recognition of the accident.

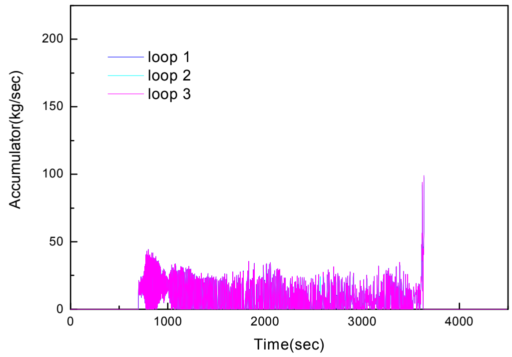

Fig. 5 Injected flow rate in accumulator

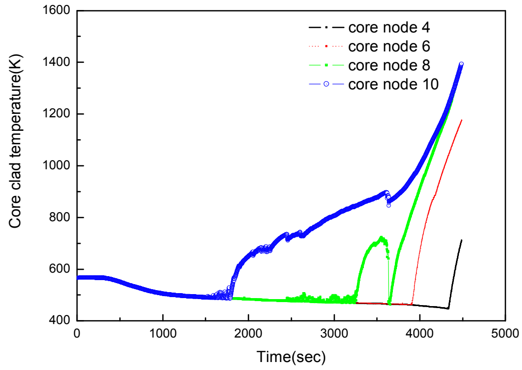

Fig. 6 Fuel cladding temperature

4. Conclusion

The evaluation of the success criteria for the newly optimized OAT was performed by using the NPA code for the LOCA in the Mode-3. In order to obtain the technical background for the proper operational procedure, a lot of sensitivity studies were performed during the low mode operation under the LOCA. In the Mode-3, the minimum action time required for the operation during the LOCA is 33 minutes.

In conclusion, to implement the license amendment for the operation at the up-rated power, utilities must re-evaluate the current operational procedures with the methods suggested in this study.

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