Development of Abnormal Operating Strategies for Station Blackout in Shutdown Operating Mode in Pressurized Water Reactor

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1. Introduction

Loss of all AC power is classified as one of multiple failure accident by regulatory guide of Korean accident management program. Therefore we need develop strategies for the abnormal operating procedure both of power operating and shutdown mode. This paper developed abnormal operating guideline for loss of all AC power by analysis of accident scenario in pressurized water reactor.

2. Analysis of Accident Scenario

In case of loss for all AC power in pressurized water reactor (PWR), the operator makes a diagnosis for the loss of ultimate heat sink and takes action to change operating mode by a procedure of the plant.

Residual heat removal of core, pressurizer pressure level and water level control is not available in case of loss of all AC power. Operating strategies to prevent core uncover depend on initial plant states. RCS is isolated if all AC power is lost in RCS intact state of cold shutdown mode. Temperature and pressure of RCS rise by core decay heat. RCS pressure is maintained at 20~30bar by charging line. RCS temperature is stabilized at intermediate shutdown mode by natural circulation using available steam generator steam dump.

The plant states of RCS vent path of refueling mode and maintenance mode are considered as two case of the accident. The refueling mode case is safe because reactor cavity is filled with water and it takes long time to boiling. The SBO in Maintenance cold shutdown mode with mid-loop operation is most risk to core covery because steam generator is not available and water level is very low. Core decay heat cooling is established by SG steam dump or gravity feed through spent fuel pool cooling system from RWST.

3. Initial and Boundary Condition of Analysis

The initial and boundary condition of the analysis as shown in Table 1 are assumed as core thermal power, operating mode and RCS temperature / pressure.

Table 1. Initial and Boundary Condition

Parameter	RCS closure	RCS open
Core thermal Power (MWt)	25	14
Operating Mode	Intermediate Cold shutdown	Normal cold shutdown
RCS	170 ℃ 30 bar	110 ℃ 5 bar

4. Accident Scenario Analysis

4.1 Scenario for intact RCS without operator action

Using Relap code, these scenarios were analyzed to verify the operator action and setpoint of the procedure.

After SBO, RCP starts coastdown and stops residual heat removal system. Water of core starts to boil at 95 minutes and safety valves of SG are opened at 197 minutes. By natural circulation, decay heat of core (25 MWt) was removed and the core was stabilized at temperature of 290 ℃ and pressure of 160 bar. Water level of SG maintained at normal level by steam driven turbine aux feed water pump.

4.2 Scenario for opened RCS without operator action

This scenario assumed that SG manway was opened. After ABO, RHR stopped and core temperature rise rapidly because core decay heat cannot be removed. Therefore, RCS starts to boil at 3 minutes and core uncovery occurred at 65 minutes. From this result, we can draw a conclusion that operator action should start within 60 minutes to maintain the integrity of core fuel.

4.3 Scenario for intact RCS with operator action

From the analysis, if SG auxfeed water is provided steadily, core decay heat can be removed for long time. RCS temperature and pressure were stabilized at intermediate shutdown mode and operator can cope with the SBO with sufficient interval.

4.4 Scenario for opened RCS with operator action

This scenario injected cold water at 60 minutes after SBO from RWST by gravity feed. Therefore, core was stabilized by the safety injection without rising temperature of RCS water. It is possible to inject the cold water from RWST to RCS by gravity feed because RWST is located higher than RCS and RCS is opened and is in atmosphere state.

5. Results of Analyses

Figures(1-3) show behavior of reactor core without operator action after SBO. Figures(4-5) show behavior of reactor core when safety injection is actuated with operator action after SBO 1.5 hours.

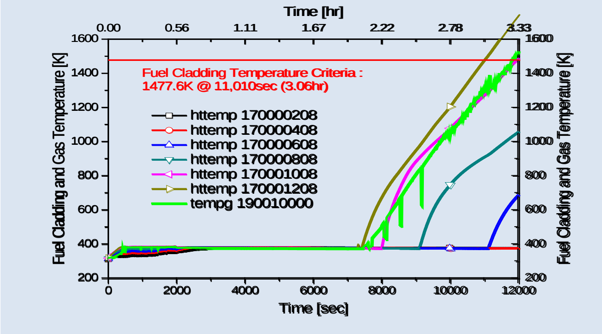

Fig 1. Fuel Temperature after SBO

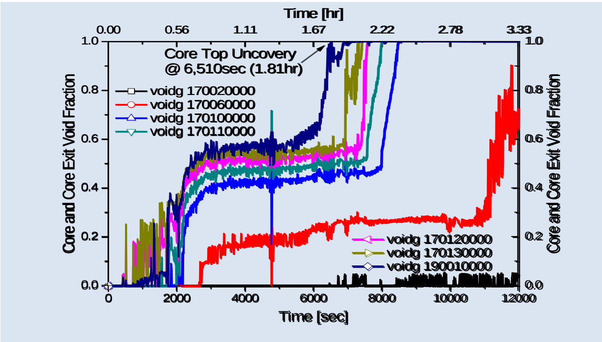

Fig 2. Void Fraction after SBO

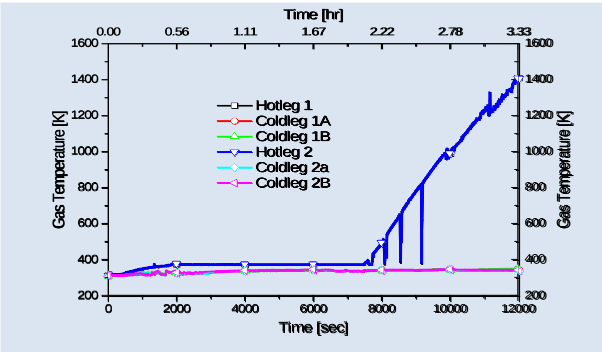

Fig 3. Vapor Temperature after SBO

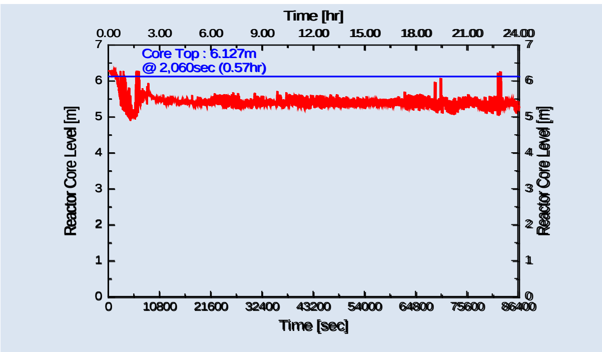

Fig 4. Safety Injection after SBO 1.5 hours

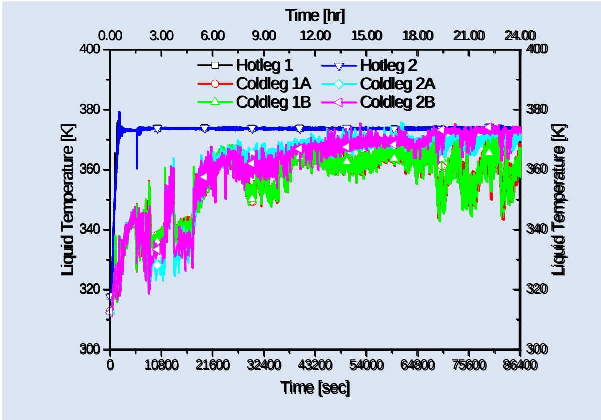

Fig 5. Safety Injection after SBO 1.5 hours

6. Conclusions

This paper analyzed the extended SBO in shutdown operating mode and developed the operating strategy of the abnormal operation procedure. Also we performed the analysis of various scenarios that operator actions are taken in shutdown SBO. Therefore, we verified the plant behavior and decided operator action to be taken in time.

From analysis results of the SBO, the fuel of core maintained in safe state for 500 minutes and 60 minutes respectively in intact or opened RCS states for intermediate cold shutdown mode after the SBO occurred. Therefore, operator action for the emergency are not required to take in 500 minutes and 60 minutes in intact and opened RCS state respectively.

These strategies and operator actions in procedure can deduce safe shut down. Therefore, the procedure showed that restore successfully the SBO accident.

7. References

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