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Development of Abnormal Operating Strategies for Loss of Ultimate Heat Sink (LOUHS) at Shutdown Mode in Westinghouse Type Nuclear Power Plant

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1. Introduction

Loss of ultimate heat sink 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 ultimate heat sink (LOUHS) at shutdown mode by analysis of accident scenario in Westinghouse Type Nuclear Power Plant.

2. Accident scenarios

We performed analysis to develop Abnormal operating guideline for loss of shutdown ultimate heat sink (LOUHS) about accident scenario as shown in table 1. Initial conditions of these scenarios are intermediate shutdown and mid-loop operation mode. Operation strategies are cooldown by SG, spent fuel pool cooling system, gravity feed from RWST, safety injection from RWST.

Table 1. Accident scenario for shutdown LOUHS

ID	Accident scenario	Initial condition
1	No operator action (RCS boundary closed)	Intermediate shutdown
2	No operator action (RCS boundary opened)	Mid-loop operation
3	Intermediate shutdown operating by SG (RCS boundary closed)	Intermediate shutdown
4	Cooldown by Spent fuel pool cooling system (RCS boundary opened)	Mid-loop operation
5	Gravity feed from RWST(RCS boundary opened)	Mid-loop operation

3. Accident Analysis Method

Accident analysis was performed in order to develop the abnormal operation guideline of shutdown LOUHS. The accident initiated from intermediate shutdown mode and took equipment actuation and operator action as shown in table 2. Loss of component cooling water system (CCWS) and component cooling sea water system (CCSWS) occurred at staring point of the accident. Stop of Steam dump valve open RCP and RHR pump occurred at 15 minutes because some cooling water are remained in their system after component cooling water stopped. RCS is stabilized in intermediate shutdown mode because SG steam dump valve control, auxiliary feed water control and charging flow control are established continuously

Table 2. Accident and Operator Action

Time(min)	Accident and Operator Action
0.0	Loss of component cooling water(CCW) and component cooling sea water(CCSW)
15.0	RCP and RHR pump stop CCW, CCSW pump stop Steam dump valve open
25.0	SG Steam dump valve control Auxiliary feed water control Charging flow control
35.0	Stabilized in intermediate shutdown (PZR pressure < 25 bar, Cold-leg temp< 170ºC

4. Accident Analysis Results

The scenario ID1 takes no operator action in RCS boundary closed state. Therefore RCS temperature and pressure rose rapidly and reached boiling point at 97 minutes. The scenario ID2 takes no operator action in RCS boundary opened state. Core in this scenario is early uncovered at 73 minutes because water in mid-loop operation is small relatively in atmosphere pressure condition. The scenario ID3 takes cooldown to intermediate shutdown mode by SG steam dump with RCS boundary closed state. Residual heat of core was removed by natural circulation in RCS, auxiliary feed water and steam dump. Behavior of RCS temperature and pressure was stabilized at 35 minutes after accident initiated. The scenario ID4 and 5 take cooldown by Spent fuel pool cooling system and gravity feed into RCS from RWST with RCS boundary opened state. Behavior of RCS temperature and pressure was stabilized at 50 minutes after accident initiated because it takes a lot of time to make the operator action to align gravity feed from RWST. However, we could reach at stabilization of RCS before core uncover occurred. If RCS pressure and temperature rise continuously above 25 bar and 170ºC respectively with RCS boundary closed states, the safety injection should initiate by operator action. If RCS temperature rises continuously above 93ºC respectively with RCS boundary opened states, the safety injection should initiate by operator action. These operating strategies are basic operating action to protect the fuel of core with safety and reliance.

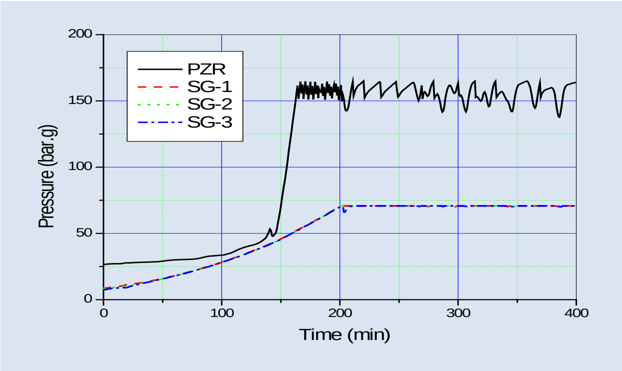

Fig 1. PZR Pressure in Scenario ID1

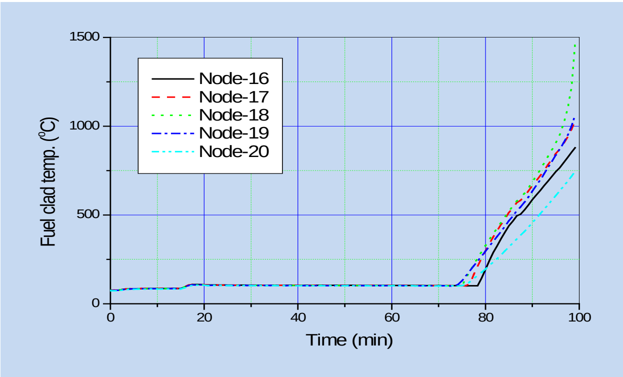

Fig 2. Fuel Clad Temperature in Scenario ID2

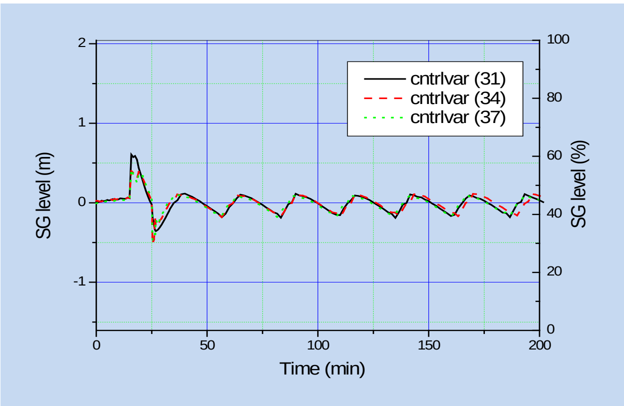

Fig 3. SG Water Level in Scenario ID3

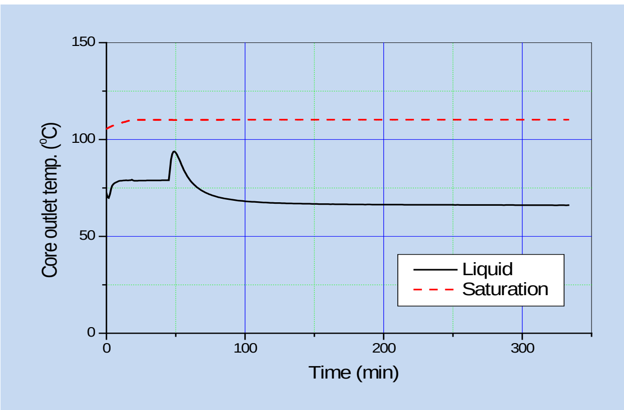

Fig 4. Core Outlet temperature in scenario ID4 and 5

5. Conclusions

This paper analyzed the loss of ultimate heat sink (LOUHS) in shutdown operating mode and developed the operating strategy of the abnormal procedure. Also we performed the analysis of limiting scenarios that operator actions are not taken in shutdown LOUHS. Therefore, we verified the plant behavior and decided operator action to taken in time in order to protect the fuel of core with safety.

From the analysis results of LOUHS, the fuel of core maintained without core uncovery for 73 minutes respectively for opened RCS states after the SBO occurred. Therefore, operator action for the emergency are required to take in 73 minutes for opened RCS state.

In RCS boundary opened state, Second strategy is to initiate safety injection by gravity feed from RWST. Third strategy is to cooldown by using spent fuel pool cooling system. This method required to change the plant design in some plant.

In RCS boundary closed state, first abnormal operating strategy in shutdown LOUHS is first abnormal operating strategy in shutdown LOUHS is to remove the residual heat of core by steam dump flow and auxiliary feedwater of SG.

These strategies and operator actions in procedure can deduce safe shutdown. Therefore, the procedure showed that restored successfully the LOUHS accident in shutdown operating mode.

6. References

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