Transactions of the Korean Nuclear Society Autumn Meeting
Yeosu, Korea, October 25-26, 2018

Study on Effect of Operator Action on Shin-Kori Unit 1 Total Loss of Feedwater Accident

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1. Introduction

A new regulatory rule was introduced in Korea, which requires analysis of multiple failure accidents in nuclear power plants. One of the multiple failure accidents is total loss of feedwater(TLOFW), which assumes loss of main feedwater and auxiliary feedwater. In analysis of multiple failure accidents, best estimate method can be used. This includes operation actions that might mitigate the accident. In this paper, sensitivity analysis is performed assuming various operator actions during the progress of the accident. The reference plant is Shin-Kori Unit 1, which is a OPR1000 type reactor. The computer code used for the analysis is RELAP5 /MOD3.3.

2. Description of the Event

2.1 Description of Feedwater System

The main feedwater system supplies feedwater to the steam generator secondary side. If the main feedwater system fails and steam generator water level falls below certain value, auxiliary feedwater system supplies emergency feedwater to steam generator secondary side to remove decay heat from the reactor. The auxiliary feedwater system for Shin-Kori Unit 1 consists of 2 motor driven pumps and 2 turbine driven pumps. The motor driven pump can be powered from emergency diesel generators in case of loss of off-site power. The turbine driven pumps use steam produced from steam generators as power source for the pump. The turbine driven auxiliary feedwater pumps can operate even in the event of station blackout.

2.2 Description of the TLOFW

Because of diversity and redundancy of auxiliary feedwater system, no single failure can result in loss of auxiliary feedwater. However, the TLOFW event assumes loss of both main feedwater and auxiliary feedwater. Since no feedwater is supplied to the steam generator secondary side, the decay heat cannot be removed through the steam generator. To remove heat from the core, feed and bleed operation is used. The operator opens the pressurizer Safety Depressurization System (SDS) valves to decrease RCS pressure and use safety injection pumps to inject cold water into the RCS. Once the primary side pressure and temperature is reduced to the point of shutdown cooling system operation, the shutdown cooling system is used for heat removal and the plant is stabilized. Depending on number of SDS valves opened, two cases are analyzed. For normal case, 2 SDS valves open at 30 minutes after the first opening pressurizer safety valve. All safety injection pumps are assumed to operate. For single failure case, 1 SDS valve opens at the time of the first opening pressurizer safety valve and only one train of safety injection pumps are assumed to operate. In this paper, single failure case is selected for sensitivity analysis.

3. Analysis Method

3.1 Description of the Computer Code

For TLOFW analysis, RELAP5/MOD3.3 Patch05 code was used. The RELAP5 code is a thermal hydraulics code for light water reactor transient analysis. The RELAP5 code was developed by Idaho National Engineering Laboratory (INEL) for USNRC. The code uses 2-fluid 6-equation model. The RELAP5 code is widely used for nuclear power plant safety and transient analysis.

3.2 RELAP Input

The RELAP nodalization of the Shin-Kori Unit 1 consists of 264 volumes and 311 junctions. Shin-Kori Unit 1 has 2 loops. Each loop has one steam generator (SG), one hotleg, two coldlegs and two RCPs. The core section has two channels: one average channel and one hot channel. Each channel has 20 axial volumes. A 10000 second steady state calculation was performed before the transient calculation.

3.3 Operator Actions

Operator actions considered in the base case calculation are manual RCP trip and opening of SDS valve. Through review of plant operating procedures, additional operator actions for sensitivity analysis were identified. Cases analyzed are shown in table 1.

Table I: Cases for Sensitivity Analysis

Case	Description
A	Base case (RCP trip, SDS valve open)
B	Pressurizer heater off at SDS opening
C	Maximize charging flow
D	Safety injection tank isolation

4. Calculation Results

4.1 Base Case Transient Calculation Result

At t=0 sec, the main feedwater to the steam generator secondary side is lost. This results in reduction of steam generator water level and eventual to reactor trip on low steam generator water level. As SG level continues to drop, U-tubes are uncovered and heat transfer area is reduced. Due to decrease in heat removal, RCS pressure increases. 10 minutes after reactor trip, the RCPs are manually stopped. The RCS pressure continues increase and reach pressurizer safety valve(PSV) opening setpoint. As PSV opens and SDS valve also opens by operator action. The RCS pressure decreases quickly to saturation pressure. Around 1000~2000 sec., the pressurizer is almost filled with water and volumetric flowrate through SDS valve is low. This leads to increase in RCS pressure. As pressurizer level decreases, volumetric flowrate through SDS increases and RCS pressure decreases as shown in Fig. 1. With decrease in RCS pressure, safety injection flowrate increases and core level increases as shown in Fig. 2.

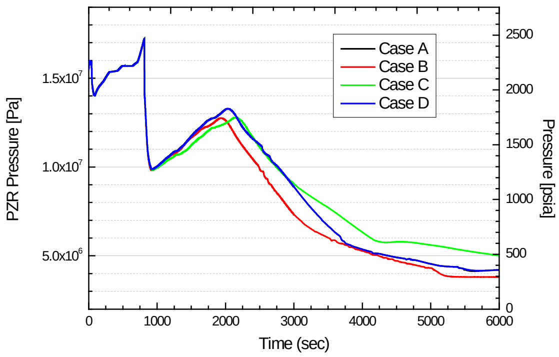

Fig. 1. Sensitivity analysis results for pressurizer pressure

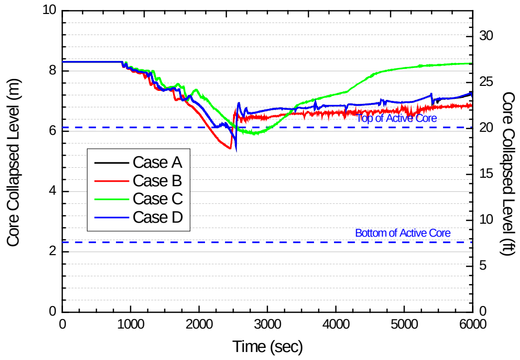

Fig. 2. Sensitivity analysis results for core collapsed level

4.2 Sensitivity Analysis Results

For Case B, the pressurizer heater was turned-off at the SDS valve opening. This resulted in lower RCS pressure than base case, which would allow faster transition to shutdown cooling system and termination of feed and bleed operation. For Case C, the charging flow rate was increased to maximum. This resulted in higher RCS pressure, but core collapsed level was higher than base case. Higher core water level means more safety margin against fuel damage. For Case D, safety injection tanks were isolated. However, even for the base case, safety injection tanks work at low pressure and amount of water injected was small. The effect of safety injection tank isolation was negligible for the time span calculated in this study (~6000 seconds). For all cases analyzed, the peak cladding temperature remained well below the 2,200˚F limit.

5. Conclusion

The total loss of feedwater accident was analyzed and sensitivity analysis performed with RELAP5/MOD3.3 code. The reference plant was Shin-Kori Unit 1. Sensitivity analysis of operator action was performed for single SDS valve actuation case. The results show that turning off pressurizer heater resulted in faster depressurization of RCS which allows faster transition to shutdown cooling system. Maximizing charging flow help increase core collapsed level. Therefore current operating procedures are appropriate in mitigating the TLOFW event.

REFERENCES

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