ANALYSIS OF A POSTULATED ELAP EVENT IN MAANSHAN NPP USING TRACE CODE

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ABSTRACT

In this study, the TRACE code was used to evaluate the postulated Extended Loss of AC Power(ELAP) accident in Maanshan nuclear power plant(NPP), determining whether RCS water level will drop down below Top of Active Fuel (TAF) while the 5th diesel generator and gas turbines are all disabled when the accident occurred. This research will run a base case without any mitigation strategy, and 4 cases with multiple mitigation strategy under different conditions. In addition, the scenario and assumptions of ELAP event in this study was referred to the WCAP-17601-P report. According to the results of simulation, it can be found that all 4 cases in this study can keep RCS water level above TAF, ensuring the safety function of reactor. Though the seal leakage rate of results can be very different in each cases under different condition.

This study successfully develops a method to analyze the mitigation capability of URG and FLEX strategy. The results can help the decision making of mitigation strategy during NPP severe accident.

1. Introduction

After the Fukushima accident, from many investigative reports, Station Blackout(SBO) situation may be longer than we have concerned. The emergency response guidelines of severe accident should be modified. To cope with such event, Taiwan Power Company(TPC) has developed a method called Ultimate Response Guidelines(URG), which gives operators the rights taking emergency steps to avoid the reactor core melting or the hydrogen accumulation inside the containment. Once either AC power or water supply can’t be restored in time, or there’s an earthquake and tsunami larger than safe shutdown, URG will be activated. The main action of URG including 2 steps depressurization, alternative water injection and containment venting. In addition, US NRC also developed a mitigation strategy called Diverse and Flexible Coping Strategy(FLEX) to tackle with such extended SBO condition. The main purpose of FLEX was to support key safety functions by providing multiple means of power and water supply, which can mitigate the consequence of beyond design basis external event.

In this study, TRACE code was used to evaluate the postulated (ELAP) accident in Maanshan nuclear power plant, determining the effectiveness of URG and FLEX. TRACE was developed by U.S. NRC, which is for NPP thermal hydraulic analysis, and usually applied to analyze the transients or accidents at nuclear power plant. In addition, Maashan TRACE model has been built in previous study [1]. Maanshan nuclear power plant is a 2-units Westinghouse 3-loops PWR power station. The accuracy and availability of Maanshan NPP TRACE model has been verified by the comparison between FSAR data and Maanshan startup test data.

2. Methodology

To determine the severity of ELAP event and the mitigation capability of URG and FLEX strategy, this research will run a base case without any mitigation strategy, and 4 cases with multiple mitigation strategy under different conditions. All the cases were in a situation of ELAP event. The scenario and assumptions of ELAP event in this study were referred to the WCAP-17601-P report [2].

In base case, we assumed an earthquake occurred at 1 minute which resulted in reactor scram, MSIV closure and RCP seal leakage. Seal begins to leak at a rate of 5gpm per loop at the moment and rises up to 21gpm per loop 13 minute later due to the flashing across seal face. Two hours after earthquake, there is a control depressurization activated on the secondary side to maintain SG pressure at about 300 psia. In this case, TDAFP is assumed to be available at all times. Table 1 shows the time sequence of the base case.

In cases with multiple mitigation strategy, unlike base case, we assume that seal begins to leak at a rate of 21gpm per loop as earthquake occurred at 1 minute. Control depressurization will also be activated at the moment. In case 1 and 2, each cases will follow URG strategy while the ELAP event lasts for more than 8 and 24 hours. Otherwise, in case 3 and 4 we assume that the plant has FSG high pressure injection equipment. Each cases will follow FLEX strategy once ELAP event lasts for more than 8 and 24 hours. The main difference between URG and FLEX is that in case 3 and 4, owing to the FSG high pressure injection equipment, there is no need to evaluate emergency depressurization. The time sequence of each cases are listed on table 2.

Event (Base case)	Time(min)
Start of simulation	0
Reactor Scram Loss of all AC power (SBO) TDAFP on Seal leakage rate 5gpm/loop	1
Seal leakage rate rise up to 21gpm/loop	14
Control depressurization, SG pressure depressurize to 21kg/cm² (300psi)	120
End of simulation	…

Table 1. Time sequence of base case

Event	Time(min)			
	Case 1	Case 2	Case 3	Case 4
Start of simulation	0			
Reactor Scram Loss of all AC power (SBO) TDAFP on Seal leakage rate 21gpm/loop Control depressurization, SG pressure depressurize to 21kg/cm² (300psi)	1			
Emergency depressurization, SG pressure depressurize to 3 kg/cm²	480(8hr)	1440(24hr)	-	-
TDAFP off Fire pump 800gpm(35.704 Kg/s) to SG Hydro-Test pump 25gpm(1.14 Kg/s) to RPV	480(8hr)	1440(24hr)	-	-
TDAFP off FSG pump 215gpm(9.595Kg/s) to SG FSG pump 40gpm(1.79 Kg/s) to RPV	-	-	480(8hr)	1440(24hr)
End of simulation	4800(80hr)			

Table 2. Time sequence of cases with mitigation strategy

3. Results and discussions

In all cases, the SBO started at 1 minute. The SG water level kept at full water level since TDAFP was available. In base case, without any mitigation measure, RCS water level dropped down below TAF at 61.89hr because of the seal leakage. It should be noticed that once RCS water level dropped down to the elevation of seal break(7.92m), there would be an oscillation on seal leakage rate since there were no coolant but steam still leak out from seal at the moment.

According to the results of simulation, it could be found that all 4 cases with mitigation strategy in this study could keep RCS water level above TAF, ensuring the safety function of reactor. In addition, through the comparison between case1.2 and case 3.4, RCS could cooldown effectively during transient with the action of subsequent depressurization in URG strategy. Since not only could it reduce the break flow rate from seal leakage, but also get the accumulator makeup with RCS, which provide coolant and increase water level and bulk boron concentration in RCS. Through the simulation results, cases with subsequent depressurization could recover RPV to full water level 6 hours earlier than the one without subsequent depressurization. Figure 1~4 showed base case results, and the results of cases with mitigation strategy are shown in Figure 8~12.

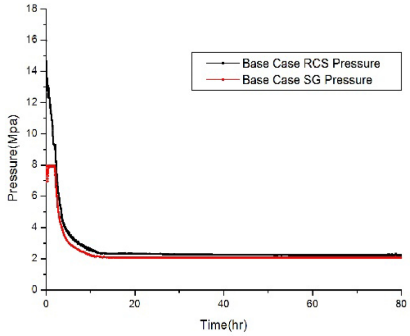

Figure 1. RCS&SG pressure of base case

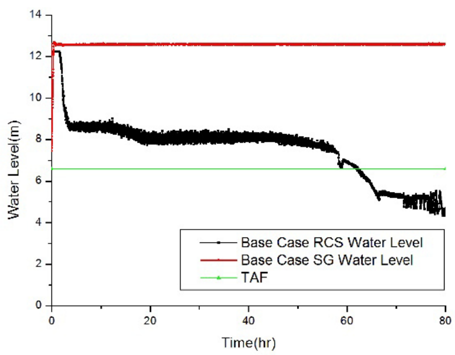

Figure 2. RCS&SG water level of base case

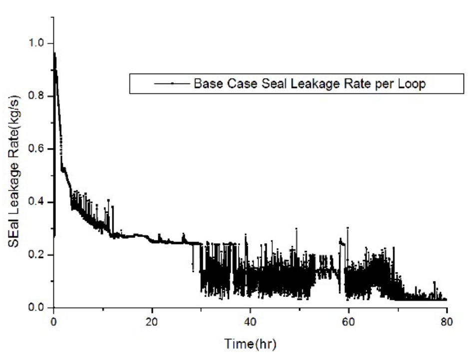

Figure 3. Seal leakage rate of base case

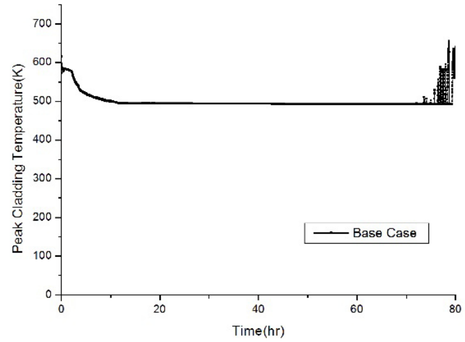

Figure 4. Peak cladding temperature of base case

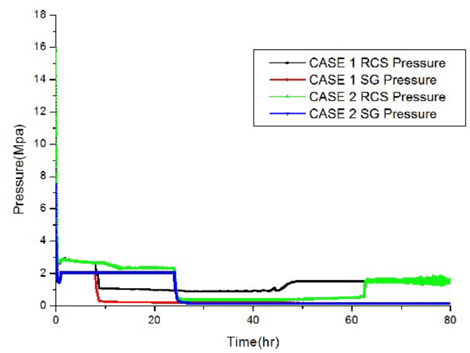

Figure 5. RCS&SG pressure of case1&2

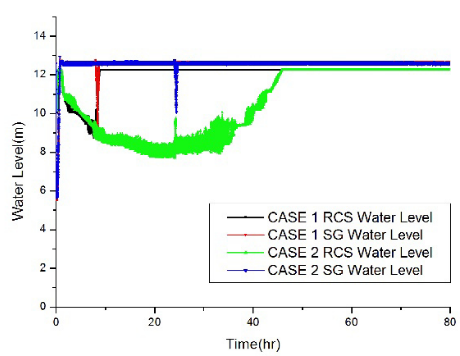

Figure 6. RCS&SG water level of case1&2

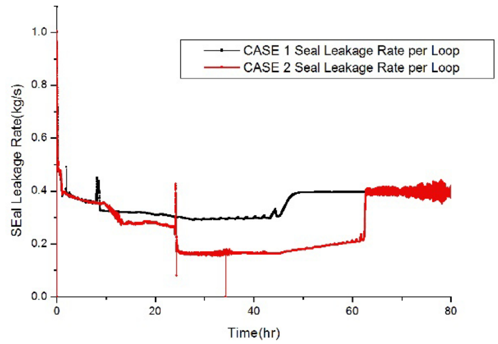

Figure 7. Seal leakage rate of of case1&2

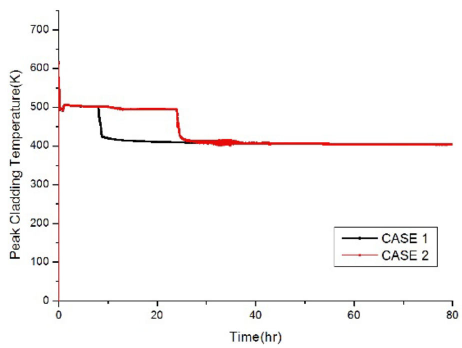

Figure 8. Peak cladding temperature of case1&2

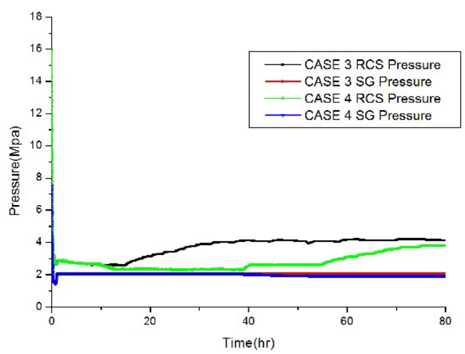

Figure 9. RCS&SG pressure of case3&4

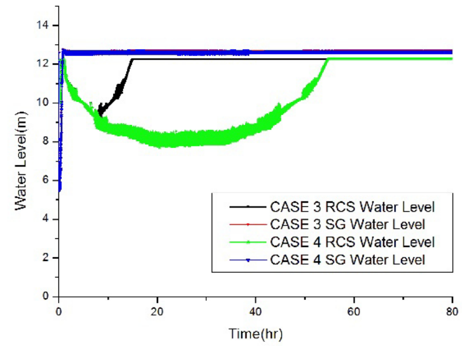

Figure 10. RCS&SG water level of case3&4

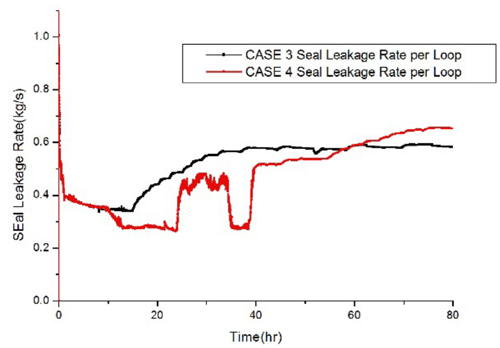

Figure 11. Seal leakage rate of of case3&4

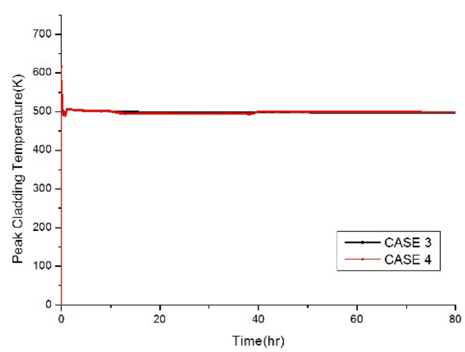

Figure 12. Peak cladding temperature of case3&4

4. Conclusions

By using TRACE code, this study has developed a method to simulate the ELAP event of Maanshan NPP. Several conclusions are as follows:

- Once ELAP event occurred, there were about 60 hours to prepare multiple means of power and water supply to keep NPP in safe.
- The action of two steps depressurization could reduce the break flow rate from seal leakage rate effectively but still kept RCS water level above TAF.
- Two-step depressurizations could extend the time available to cope with the lineup of the alternate water
- This study successfully built a method of consequence analysis of Maanshan NPP and the results can help the decision making of mitigation strategy during the ELAP accident.

Reference

[1] Huang, Kai-Chun, Shih, Chunkuan, Wang, Jong-Rong, 2013, Analysis of Maanshan Station Blackout Accident and Ultimate Response Guideline using TRACE Code

[2] Nuclear energy institute, 2012, Diverse and Flexible Coping Strategies (FLEX) Implementation Guide

[3] J. Hartz, M. Janke, M. Wilcox, A. Goulet, V. Esquillo, 2012, Reactor Coolant System Response to the Extended Loss of AC Power Event for Westinghouse, Combustion Engineering and Babcock &Wilcox NSSS Designs

[4] H. Esmaili, D. Helton, D. Marksberry, R. Sherry, P. Appignani, D. Dube, M. Tobin, R. Buell, T. Koonce, J. Schroeder, 2011, Confirmatory Thermal-Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models—Surry and Peach Bottom