EFFECTIVENESS OF DEPRESSURIZATION AND INJECTIONS STRATEGIES DURING EXTENDED SBO FOR CHINSHAN BWR/4 NPP

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ABSTRACT

Taiwan Power Company has proposed a set of Ultimate Response Guideline (URG), in addition to existing EOP, to tackle with such extended SBO situation. There are three main operations in the URG, two-step depressurization, water injection, and containment venting. There are three initiating conditions and either one will enter into URG. The main purpose of URG is to maintain the cooling capability and the containment integrity. In this study, the URG effectiveness of Chinshan NPP will be discussed. Depending on the success of each of three operations, there are six cases under considerations in this study. The basic case assumed an earthquake occurred at 300 seconds which resulted in reactor scram and MSIV closure. At 2100 seconds, a tsunami hit the plant and finally a total EDG failure, and hence SBO, occurred at 3905 seconds. RCIC was assumed to last for only one hour and the low pressure alternate water was injected into the core at 6700 seconds. Other cases include failure to perform complete two-step depressurization, and with or without water injection. Current results showed that the two-step depressurization could extend the time available to cope with the lineup of the alternate water.

1. Introduction

After Fukushima Daichii accident, many severe accident researches have been studied widely. In Taiwan, there are two BWRs and one PWR nuclear power plants (NPP) operating. Chinshan NPP is BWR/4 with Mark I containment. Meanwhile, Taiwan Power Company (TPC) developed a series of strategies, known as Ultimate Response Guideline (URG), in addition to existing EOP, to tackle with such extended SBO scenario. In URG, there are three main actions, two-step depressurizations, low pressure water injection, and containment venting. Recently, BWROG has endorsed

URG, and will implement into the existing procedures. In the USA, FLEX was proposed to strengthen emergency power and water resources in three phases within twenty four hours into the accident.

In this study, two simulation codes, MAAP and PCTRAN, were applied to investigate the effectiveness of URG. MAAP is developed by FAI, which is a severe accident simulation code, and usually applied to analyze the transients or accidents at nuclear power plants. PCTRAN is developed by MST, and its advantage is the graphic interface and fast-running.

2. Methodology

In the previous study [1], the results of the effectiveness of Chinshan NPP URG by utilizing PCTRAN have already been presented. In this study, MAAP was utilized to assess the effectiveness of Chinshan URG. Furthermore, the minimum injection rates during the URG were also analyzed with both two codes.

There are three main operations in the URG, two-step depressurizations, water injection, and containment venting. The flowchart of URG is shown in Figure 1. The idea is to depressurize the system pressure orderly first and maintain high enough steam pressure to keep RCIC operating. Emergency depressurization is then activated when RCIC fails. There are three initiating conditions and either one will enter into URG. The main purpose of URG is to maintain the cooling capability and the containment integrity. In this study, the URG effectiveness of Chinshan NPP (BWR4, Mark-1) will be discussed. Depending on the success of each of three operations, there are six cases under considerations in this study. The basic case assumed an earthquake occurred at 300 seconds which resulted in reactor scram and MSIV closure. At 2100 seconds, a tsunami hit the plant and finally a total EDG failure, and hence SBO, occurred at 3905 seconds. RCIC was assumed to last for only one hour and the low pressure alternate water was injected into the core at 5000 seconds. Other cases include failure to perform complete two-step depressurizations, and with or without water injection. The time sequence is shown in Table 1, and the cases arrangement is listed in Table 2.

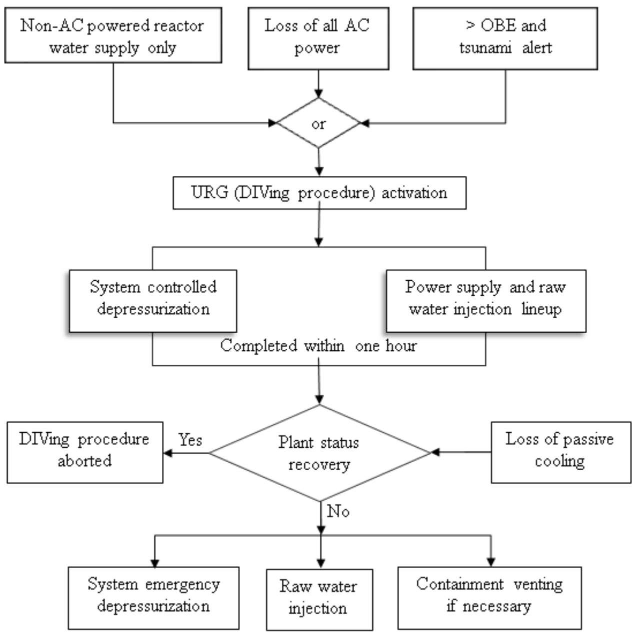

Fig 1.URG flowchart

Event	MAAP (sec)
Start of simulation	0
Reactor Scram **LOOP** **Reactor pressure drop to 35kg/cm² (1 SRV open)**	300
EDG Failure **Loss of all AC power (SBO)** **Reactor pressure drop to 15kg/cm² (1 SRV open)**	2100
HPCI / RCIC Trip **Reactor pressure drop to 3kg/cm² (5 ADS open)** **Containment vent**	3905
Injection to Core (Flow rate = 650 gpm = 40.95kg/s)	5000
End of simulation	……..

Tab 1. Time sequence of URG cases

Event/Case	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Controlled Depressurization	Y	N	N	N	Y	Y
Fully Depressurization	Y	N	Y	Y	N	Y
Low Pressure Water Injection	Y	N	Y	N	N	N

Tab 2. Strategies of six cases

3. Results and discussions

The results showed that the two-step depressurizations could extend the time available to cope with the lineup of the alternate water. If only one-step depressurization was taken at the time RCIC failed, the lowest water level would be 50 cm above TAF, compared with 300 cm above TAF with two-step depressurizations. And the safety of the NPP can be assured if the three operations of URG are fully taken. From our sensitivity analysis in Chinshan NPP with MAAP, the minimum injection rate to keep the fuel covered was only 225 gpm. With the injection rate of 200gpm, the water level would go about 20 cm below TAF for a short period, but no appreciable peak cladding temperature increase was found. But if the injection rate was only 50 gpm, the water level would go below TAF at 7300 sec and peak cladding temperature would reach

1088.7 K at 15500 sec. However, the results from PCTRAN showed that the minimum injection rate was 138 gpm. But if the flow was 125 gpm, the water level would be lower than TAF at 42000 sec and peak cladding temperature would reach 1088 K at 57000sec. Figure 2~7 showed MAAP results, and the results of sensitivity of minimum injection rate by PCTRAN are shown in Figure 8~9.

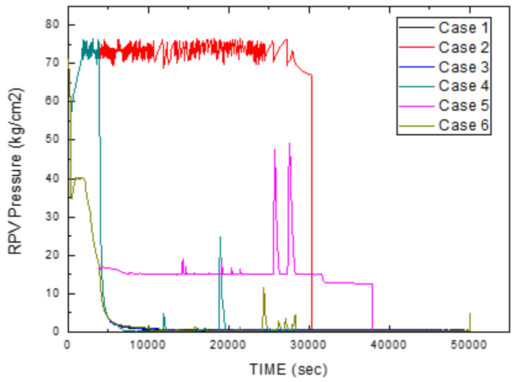

Fig 2. RPV pressures in MAAP in URG cases

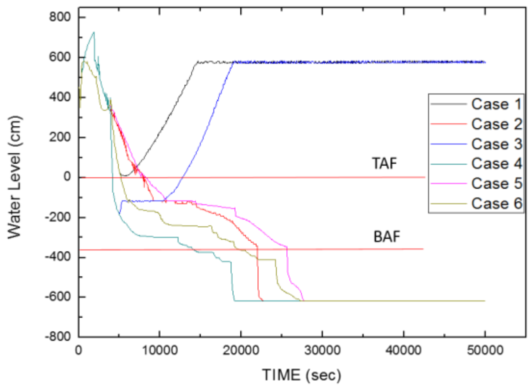

Fig 3. Downcomer water levels in MAAP in URG cases

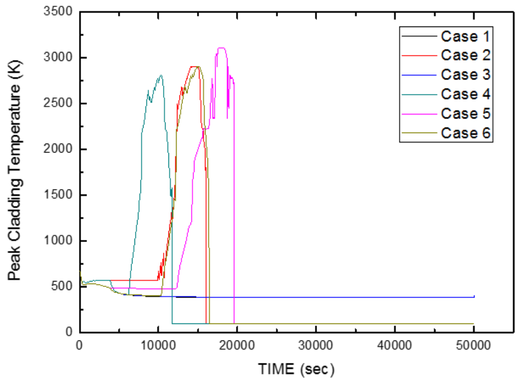

Fig 4. Peak cladding temperatures in MAAP in URG cases

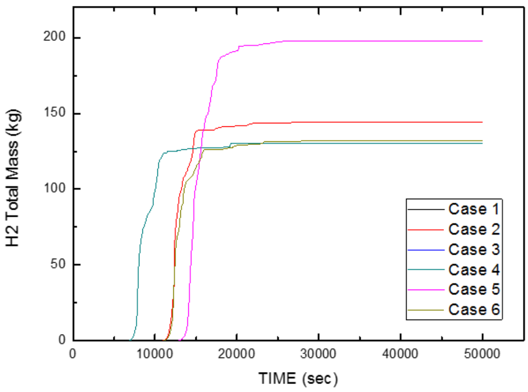

Fig 5. Hydrogen contents in MAAP in URG cases

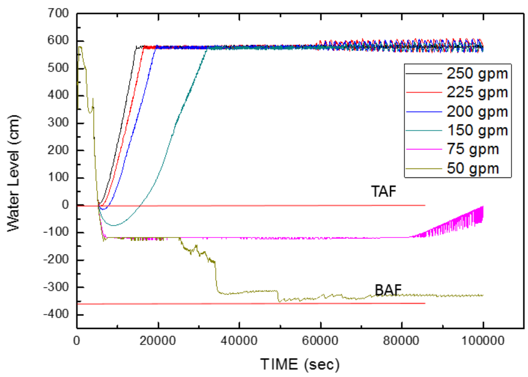

Fig 6. Downcomer water levels in MAAP with different injection rates

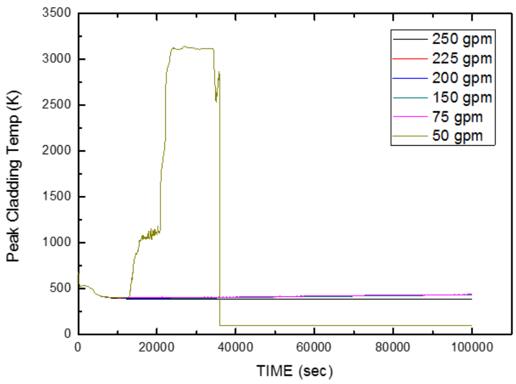

Fig 7. Peak cladding temperatures in MAAP with different injection rates

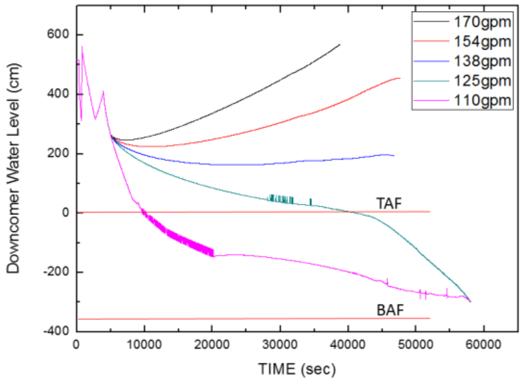

Fig 8. Downcomer water levels in PCTRAN with different injection rates

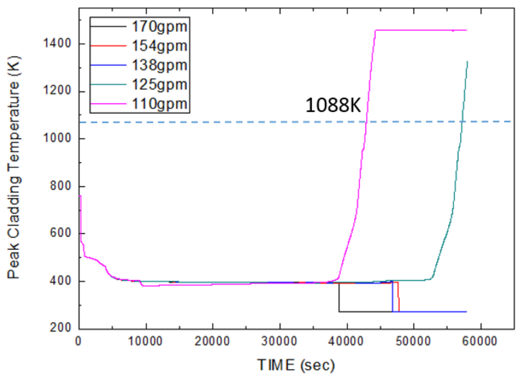

Fig 9. Peak cladding temperatures in PCTRAN with different injection rates

Conclusions

The URG strategies have been found effective to ensure the fuel covered by coolant, also prevent PCT from exceeding 1088.7K. The results from case 1 and 3 showed that two-step depressurizations were successful to extend the time of preparation of alternative water source after RCIC failed. Our current results showed the minimum injection rates to keep the water levels above TAF for Chinshan NPP were 150 gpm for MAAP and 138 gpm for PCTRAN.

Reference

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