Development of Severe Accident Management Strategies for Shin-kori #3and #4

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1. Introduction

Severe accident management is magnified as safety enhancements of nuclear power plants due to Fukushima accident in Japan. Strategies for severe accident management should be set up and included in the development process of severe accident management guidelines (SAMG). The guide for Shin-Kori#3 and #4 was developed according to government's severe accident policy in Korea.

Shin-Kori units #3 and #4 are new reactors under construction as an APR 1400 type reactor. The plants which considered coping with severe accident from design phase are different from other operating plants in view of severe accident management strategies.

The purpose of this paper is to establish optimal strategies for Shin-Kori #3 and #4. A scheme for optimized severe accident management was drawn up with the object of achieving core cooling, containment integrity, and decreased release of fission product.

2. Methods and Results

In this section, methods to select optimal strategies of severe accident management for Shin-Kori #3 and #4 were described. To draw the optimization, key design features of plants for severe accident mitigation were checked and results of probabilistic safety assessment (PSA) were reviewed to gain insights related to severe accident. Using the modular accident analysis program (MAAP) code for severe accident, coping capacity against severe accident was analyzed such as hydrogen response and containment capacity. The plan to mitigate accidents was based on the concept of defense in depth.

2.1 Design Features of Plants

Shin-Kori #3 and #4 are pressurized water reactors (PWR) as an APR 1400 type reactor and core thermal output of 3,983 MWt[1]. Four safety injection pumps (SIP), two shutdown cooling pumps (SCP), and two containment spray pumps (CSP) can provide cooling water to reactor coolant system (RCS) from in-containment refueling water storage tank (IRWST), as shown in Fig.1. Four safety injection pumps can provide cooling water during high pressure in RCS and the others can provide cooling water during low pressure in RCS. Four auxiliary feed water pumps (AFWP) can remove core heat through two steam generators (SG). Also, external cooling water using fire engines can be injected to RCS and SG as a part of Fukushima follow-up action.

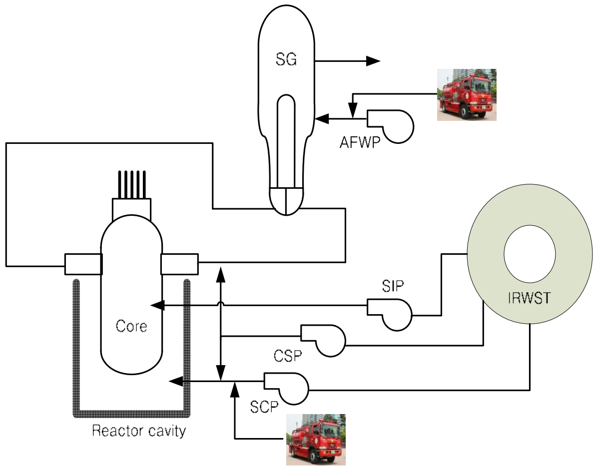

Fig.1. Core cooling method

For containment integrity, passive autocatalytic recombiners (PAR) and igniters for decrease of hydrogen concentration in containment are designed and emergency containment spray backup system (ECSBS) is installed for decrease of containment pressure. In addition, cavity flooding system (CFS) is designed.

For loss of power, emergency diesel generators (EDG), an alternate AC diesel generator (AAC DG), and a mobile generator are designed.

2.2 Review of PSA

Shin-Kori #3 and #4 PSA core damage frequency (CDF) [2] amounts to 1.09E-6/yr, which sums all CDFs of the 266 event sequences of full power internal event analysis. Station black out (SBO) is 60.8 % of CDF, and small loss of coolant accident (SLOCA) is 16.8 %. Core damage cause of SBO is failure of turbine driven AFWP due to exhausted battery and failure of SIPs and SCPs is caused to core damage in initial event of SLOCA.

Containment failure (CF) is 22 % and no CF is 78 %. 22 % of CF sums 9.1 % of late containment failure, 4.0 % of containment bypass, 3.3 % of no containment isolation, 3.0 % of early containment failure, and 2.4 % of basemat melt-through.

The dominant event of core damage is SBO and major cause of containment failure is late containment failure. A strategy for preventing containment failure is to maintain reactor vessel integrity and remove containment heat.

2.3 MAAP Analysis

For the analysis of coping capability against severe accident, nine event sequences with high frequency were chosen as shown in Table.1. Six of those were sequential events according to SBO and two events were due to loss of off-site power (LOOP). The rest was an event resulting from small loss of coolant accident (SLOCA). These events were analyzed during 24 hours.

As results of analysis, hydrogen concentration in containment did not exceed 10 % and RCS pressure through two train pressurizer pilot operated safety and relief valves (POSRV) decreased to 150 psia within 30 minutes. Also, containment pressure did not exceed 60 psig if containment spray system was actuated, while maximum pressure was 116 psia without containment heat removal systems.

Table1. Event sequences for analysis

Event	Event type	Event fraction
SSBO_S1	Seismic event	0.317
SLOOP_S219	Seismic event	0.201
SBO_S261	Internal event	0.092
SBO_S263	Internal event	0.033
SBO_S277	Internal event	0.026
FSBO_S485	Fire event	0.024
SSBO_S55	Seismic event	0.021
SLOCA_S55	Internal event	0.017
SLOOP_S220	Seismic event	0.015
Total		0.746

2.4 Selected Strategies

Strategies to mitigate severe accident were seven as shown in Fig 2; RCS depressurization, injection to SG, injection to RCS, injection to reactor cavity, controlled release of fission product, controlled pressure in containment, and controlled hydrogen concentration in containment.

The concept of defense in depth was applied to severe accident management. That is, integrity of reactor vessel was a preferential goal for delay of severe accident progression and for maintenance of containment integrity. Strategies selected for reactor vessel were RCS depressurization, injection to SG, injection to RCS, and injection to reactor cavity. RCS depressurizations were chosen for using various pumps and for preventing the high pressure melt ejection. The plan of injection to reactor cavity was selected for ex-vessel cooling.

The next defense after the core integrity was containment integrity. Overpressurization and increase of hydrogen concentration in containment were the concern for severe accident management. In accordance with the interest, decrease of pressure and hydrogen in containment was adopted for the strategies.

The last strategy after containment failure was the minimized release of fission product. Reduced release according to location was needed.

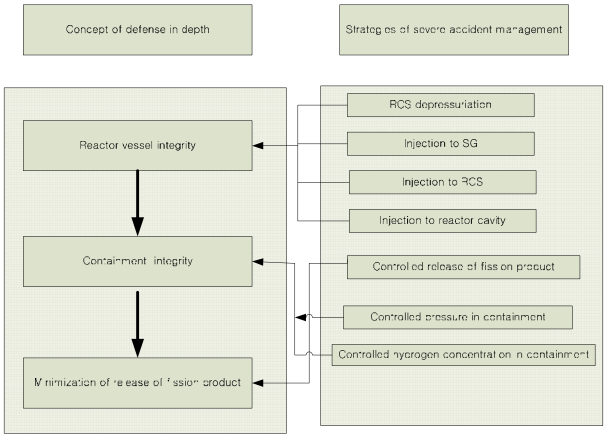

Fig.2. Selected strategies of severe accident management

3. Conclusions

Shin-Kori units #3 and #4 are a new reactor and designed to add mitigating systems for coping with severe accident such as ECSBS, PAR, and CFS. Also the plants are reflected as a part of Fukushima follow-up measures

The strategies of SAMG for Shin-Kori #3 and #4 were developed. The strategic approach was based on the concept of defense in depth. Firstly, strategies for core cooling were chosen such as RCS depressurization, injection to SG, injection to RCS, and injection to reactor cavity. Secondly, the plans for containment integrity were developed for controlling pressure and hydrogen in containment. Lastly, reduced release of fission product was considered for protection of the public after containment failure.

The achieved strategies meet the needs of effective methods for severe accident management and enhancement of safety.

REFERENCES

[1] Shin-Kori #3 and #4 FSAR (Final Safety Analysis Report), KHNP, 2010.
[2] Shin-Kori # 3 and # 4 PSA report, KHNP, 2011