Sensitivity Study for Local Air Cooler Operation using MACST for Domestic CANDU Nuclear Power Plants

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1. Introduction

In domestic CANDU 6 NPP, LAC(Local Air Cooling) and ESC(End-Shielding Cooling) systems are installed as accident mitigation systems to remove heat from reactor buildings. However, as the support systems(power and cooling water) required for LAC and ESC operations are non-seismic qualified, they are unavailable due to loss of normal power and cooling water in case of an earthquake. Therefore, an LCF(Late Containment Failure) were certainly occurred(Fig. 1).

After the Fukushima nuclear accident, MACST(Multi-barrier Accident Coping STrategy) development to maintain and restore essential safety functions in preparation for beyond design basis external events such as ELAP(Extended Loss of all AC Power) and LUHS(Loss of Ultimate Heat Sink) is actively progressing. In addition, accident response equipment (MACST equipment) necessary for performing MACST is underway.

The purpose of this paper is to evaluate the effects of the LAC operation using MACST equipment in Level 2 Seismic PSA of domestic CANDU 6 NPP during full-power operation.

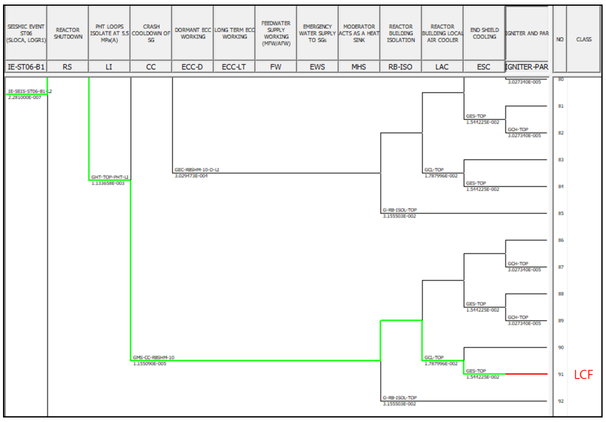

Fig 1. LCF scenario due to LAC and ESC operation failure

2. Methods and Results

In the full-power Level 2 Seismic PSA of domestic CANDU 6 NPP, LAC and ESC operations are unavailable due to loss of normal power and cooling water in case of an earthquake.

Accordingly, if alternative power and cooling water using MACST equipment are secured for LAC operation, LAC may be included as an accident mitigation measure for heat removal from reactor buildings.

2.1 Analysis Scope

In the full-power Level 2 PSA of domestic CANDU 6 NPP, LCFs caused by internal events, seismic, internal flooding and internal fire account for 2.4 %, 85.6 %, 5.6 % and 6.4 % of the total LCF, respectively.

In addition, the LCFs for each seismic acceleration range of Level 2 seismic PSA are 7.7 %(Bin#1: 0.1 g ~ 0.2 g), 16.3 %(Bin#2: 0.2 g ~ 0.3 g), 38.1 %(Bin#3: 0.3 g ~ 0.5 g), 31.9 %(Bin#4: 0.5 g ~ 0.8 g) and 5.9 %(Bin#5: 0.8 g ~ 1.0 g), respectively.

Therefore, the analysis target range for the LAC operation using the MACST equipment in the full-power Level 2 PSA was performed for all initial events induced seismic of each seismic acceleration range.

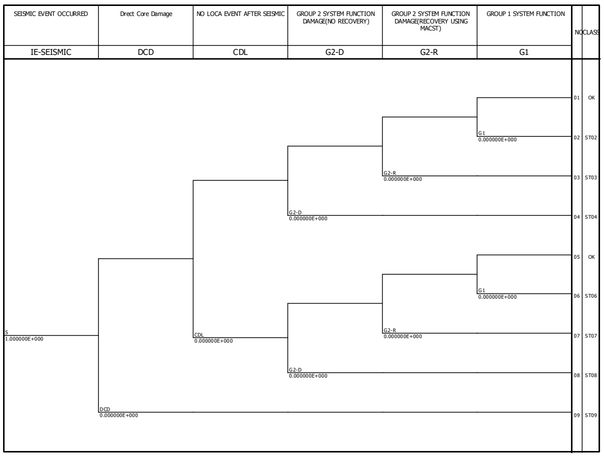

Fig 2. Initial events induced seismic in Bin#1

2.2 Additional LAC Operation using MACST Equipment

In the full-power Level 1 Seismic PSA, ECCS(Emergency Core Cooling System), EWS(Emergency Water Supply System), and MSSV(Main Steam Safety Valve) supplied with EPS(Emergency Power Supply) system which is designed for DBE(Design Basis Earthquake) Category B are operated to prevent core damage.

After core damage, LAC and ESC operations are the major heat removal measures to prevent containment failure. However, as the support systems(power and cooling water) required for LAC and ESC operation are non-seismic qualified, they can't be used as the means of removing heat from the containment.

In addition, even though EPS and EWS designed for DBE(Category B) are available in seismic, they are not line-up, so it is impossible to supply power and cooling water for LAC and ESC operation. Therefore, there are no mitigation measures to remove heat from the containment in seismic events during full power operation, so it was analyzed as a LCF.

As shown in Fig 3, if the MACST equipment can be used to supply alternative power and cooling water to a LAC operation, it can be applied as a means of removing heat from the containment in a full-power level 2 seismic event.

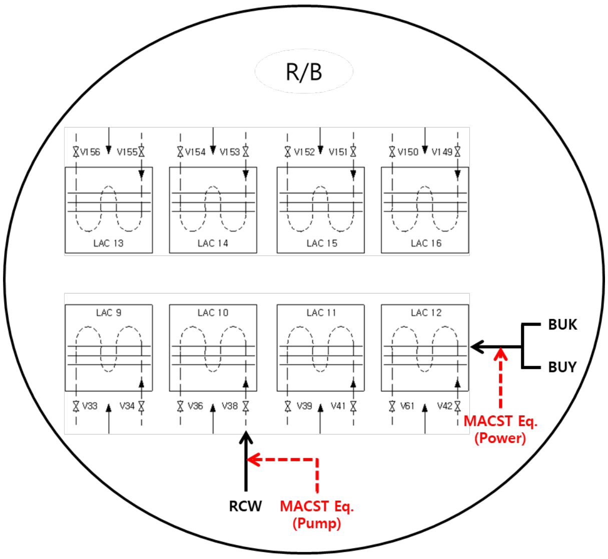

Fig 3. Schematic diagram of LAC
(MACST equipment can be used to supply alternative power and cooling water)

2.3 Assumptions and Assessment

The model used for the analysis refers to the full power level 2 seismic PSA model of a domestic CANDU 6 NPP[4].

In addition, the reliability data of the MACST equipment used as the alternative power and cooling water for the LAC are referred to NUREG/CR-6928(2015)[5]. According to the seismic acceleration range, the multiplier factors of PWROG-14003-NP(Rev00)[6](deployment factor, location factor, test/maintenance factor, water quality factor) were applied.

The MACST equipment is assumed to be seismic qualification. The HEP(Human Error Probability) of the MACST equipment is assumed to be 0.002, and according to the seismic acceleration range, the multiplier factors of EPRI-3002000709(Table 5-12)[7] were applied to the each HEP.

The dependency between fixed equipment and MACST equipment for an operator action was not considered.

2.4 Development of Sensitivity Model

In the full power level 2 seismic PSA model of a domestic CANDU 6 NPP, the alternative power and cooling water model using MACST equipment was developed and applied to the fault tree of the LAC system as shown in Fig 4.

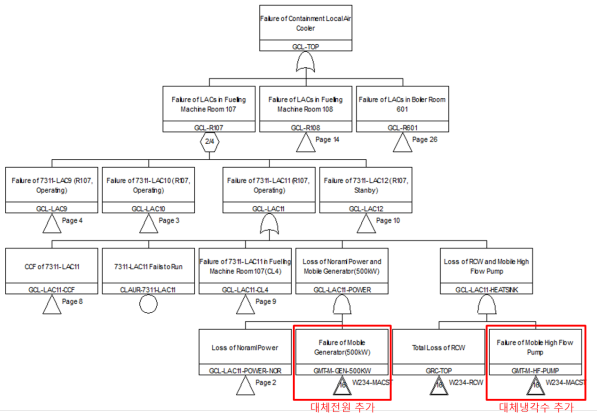

Fig 4. Development of the fault tree of LAC
(Alternative power and cooling water using MACST equipment added)

In addition, the alternative power and cooling water models for the MACST equipment including the fuel transfer pump were prepared as shown in Fig. 5 and Fig. 6.

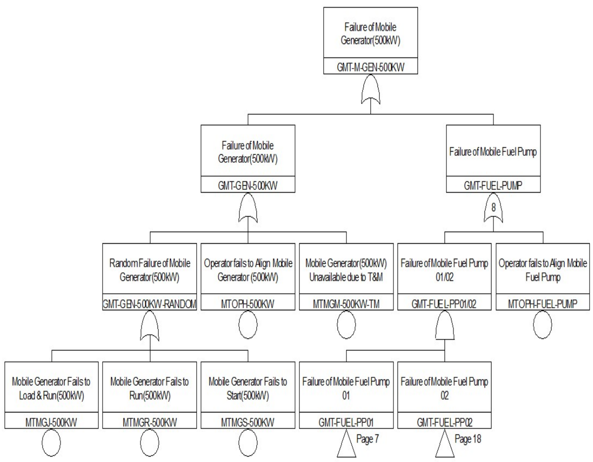

Fig 5. Development of the fault tree of alternative power

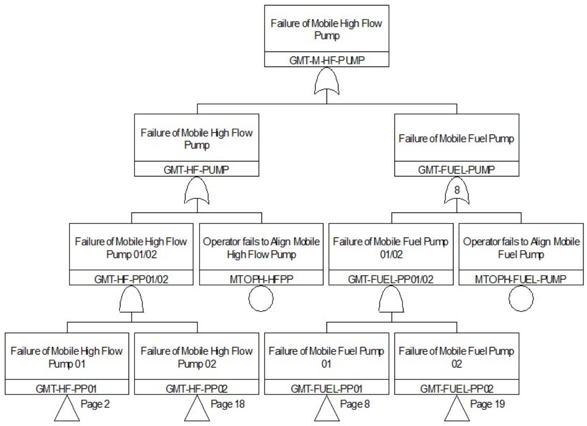

Fig 6. Development of the fault tree of alternative cooling water

3. Conclusions

Compared to the base model, the results of applying alternative power and cooling water using the MACST equipment for LAC operation in the full-power Level 2 Seismic PSA of domestic CANDU 6 NPP, show that the total CF(Containment Failure), and the LCF are reduced by 19.8 % and 20.3 %, respectively.

As shown in Table 1, "NO CF" was 0.0 % in the base model if the LCF and ESC operation were unavailable due to seismic. However, "NO CF" was 25.88 % in the case of the sensitivity analysis model.

Type		BASE(%)	CASE(%)
NO CF		0.00	25.88
CF	LCF	99.98	73.71
	VLCF	0.00	0.39
	ISO. FAIL	0.02	0.02
	BYPASS	0.00	0.00
	Total	100.00	74.12
Total (NO CF + CF)		100.00	100.00
LERF (ISO. FAIL + BYPASS)		0.02	0.02

Table 1. Comparison of the base model and sensitivity model results

In addition, in the case of the sensitivity analysis model for each seismic acceleration range, the LCFs of 8.9 % (Bin#1), 16.6 % (Bin#2: 0.2g~0.3g), 36.9 % (Bin#3: 0.3g~0.5g), 32.2 % (Bin#4: 0.5g~0.8g), and 5.4 % (Bin#5: 0.8g~1.0g) of the total LCF were evaluated.

REFERENCES

[1] CNSC, "Probabilistic Safety Assessment(PSA) for Nuclear Power Plants", S-294, 2005.

[2] AECL, "Probabilistic Safety Assessment(PSA) Report Wolsong NPP 234", 86-03600-PSA-001, Rev00, 1995.

[3] KHNP, "At-Power Seismic Events Level 1 PSA Report for Wolsong Unit 2/3/4", 2015.

[4] KHNP, "At-Power Level 2 PSA Report for Wolsong Unit 2/3/4", 2015.

[5] NRC, "Component Reliability Data Sheets 2015 Update", NUREG/CR-6928, 2017.

[6] Westinghouse, "Implementation of FLEX Equipment in Plant-Specific PRA Models", PWROG-14003-NP, 2016.

[7] EPRI, " Seismic Probabilistic Risk Assessment Implementation Guide", EPRI-TR- 3002000709, 2013.