

Sensitivity Study for Feed & Bleed Operation for Domestic CANDU Nuclear Power Plants

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1. Introduction

As a part of the action items after the Fukushima accident, FP(Full Power) and LPSD(Low Power and Shutdown) PSA(Probabilistic Safety Assessment) for domestic CANDU NPPs(Nuclear Power Plants) has been performed for the last 3 years. According to the results of this assessment, the nuclear reactor core was damaged when LOCL4(Loss of Class 4) accompanied by LOCL3(Loss of Class 3) had occurred during LPSD mid-loop operation (POS5A/5B except POS6 when man-way is opened).

The purpose of this paper is to evaluate the effects of the feed and bleed operation using DCT(Degassing Condenser Tank) over-pressure protection valves when LOCL4 with LOCL3 occurs during LPSD mid-loop operation(Figure. 1).

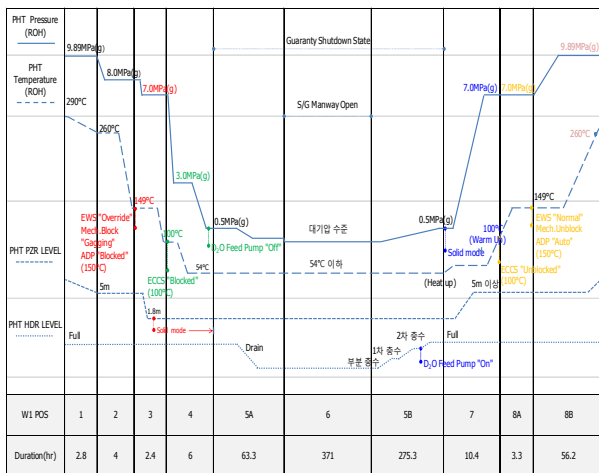


Figure. 1. POS Identification and Duration for Wolsong NPP Unit 1

2. Methods and Results

When both LOCL4 and LOCL3 occurs simultaneously during LPSD mid-loop operation, the feed and bleed operation by using the bleed line with DCT level control valves and isolation valves (3332-LCV-8/-15 and 3332-PV-16) is impossible because the valves for the bleed operation fail to close by LOCL4 and LOCL3.

Alternatively, the feed and bleed operation can be available as a mitigation system under the accidents if an additional bleed path is obtained by using DCT over-pressure protection valves(3332-RV-11/-21).

2.1 Analysis object range

The CDF(Core Damage Frequency) of Level-1 Internal Event for Wolsong NPP Unit 1 during LPSD POS5A/5B accounts for about 89.08%(POS5A: 30.04%, POS5B: 59.04%) of the total CDF. For Wolsong NPP Unit 1 LPSD External Event, seismic analysis is excluded from this study because it is PSA-based SMA(Seismic Margin Assessment based Probabilistic Safety Assessment).

The CDF of Level-1 Internal Event for Wolsong NPP Unit 2,3,4 during LPSD POS5A/5B accounts for about 91.81%(POS5A: 42.91%, POS5B: 48.90%) of the total CDF. Also, the CDF from seismic analysis of External Event is about 72.8%(POS5A: 20.6%, POS5B: 52.2%) of the total CDF. Therefore, The accident of LOCL4 coincident with LOCL3 during LPSD mid-loop operations(POS5A/5B) is selected as the representative Initial Event and POS for the analysis of the feed and bleed operation using DCT over-pressure protection valves .

2.2 Additional Feed and Bleed operation Methods

When the accident of LOCL4 coincident with LOCL3 occurs during LPSD mid-loop operation, the safety injection operation using ECCS(Emergency Core Cooling System) and EPS(Emergency Power Supply) is available, but the bleed operation is not possible because the bleed line with DCT level control valves and isolation valve(3332-LCV-8/-15 and 3332-PV-16) are not available due to LOCL4 with LOCL3 and loss of IA(Instrument Air). The reasons is that the valves for the bleed operation fail to close due to the loss of power Resulting from the exhaustion of the portable batteries and nitrogen bottles(air)(it can't be used for the mission time).

According to the result of 2015 PSA Level-1 Internal & External Events during LPSD mid-loop operation, the feed and bleed operation using DCT level control valves and isolation valve was not considered. Thus the core is directly damaged when LOCL4 with LOCL3 occurs.

If an additional bleed path using DCT over-pressure protection valves(Figure. 2) for the bleed operation will be considered, the accident of LOCL4 coincident with LOCL3 occurs during LPSD mid-loop operation is mitigated by the feed and bleed operation.

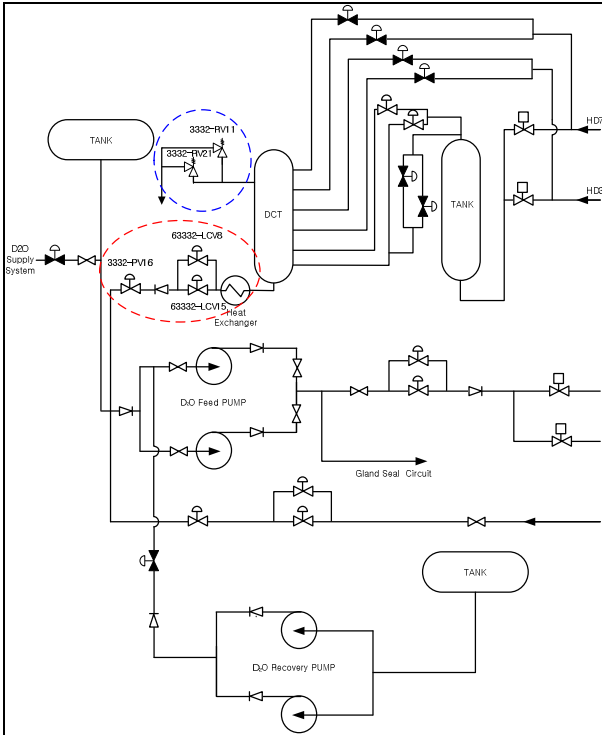


Figure 2. Schematic diagram of pressure & inventory control system

2.3 Assessment and Assumptions

The LOCL4 with LOCL3 during LPSD mid-loop operation is evaluated using domestic CANDU NPP 2015 PSA model(Wolsong Unit 1 & 2,3,4).

As bleed line, the DCT over-pressure valves(3332-RV-11/-21) must be opened by the operator at SCA(Secondary Control Area) and must be powered by EPS. The unavailability of valves including HEP (Human Error Probabilistic) on the bleed line is assumed to be 0.2.

2.4 Development of Event Tree

Figure 3 shows the ET(Event Tree) with an additional feed and bleed operation using DCT over-pressure protection valves for the LOCL4 with LOCL3 during domestic CANDU NPP LPSD mid-loop operation. The CL405ABLEED for the bleed operation is added to the event tree header accordingly.

The seismic ET during LPSD mid-loop operation for Wolsong NPP Units 2,3,4 is composed of two steps. Figure 4 shows that the primary ET divided into 18 scenarios is to simulate the form of failure mode for any system caused by the seismic. The secondary ET is the configured type of seismic ET which considers the characteristics of the available system. An additional feed and bleed operation using DCT over-pressure protection valves for the LOCL4 with LOCL3 during LPSD mid-loop operation has been applied to the applicable five secondary ETs of total secondary

ETs(total 18 ETs). Figure 5 shows the typical representative secondary ET(ST12).

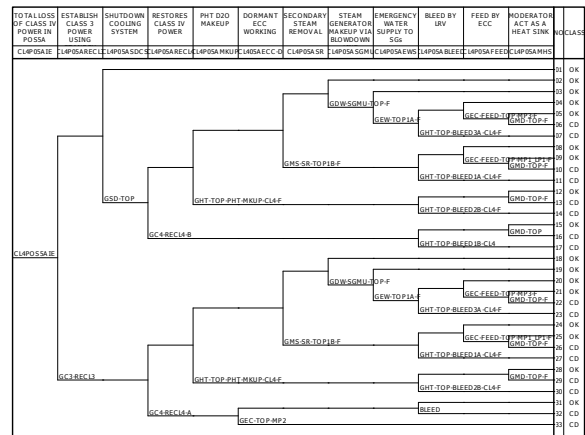


Figure 3. LOCL4 Event Tree Considered with an additional feed and bleed operation during LPSD mid-loop operation for the domestic CANDU NPP

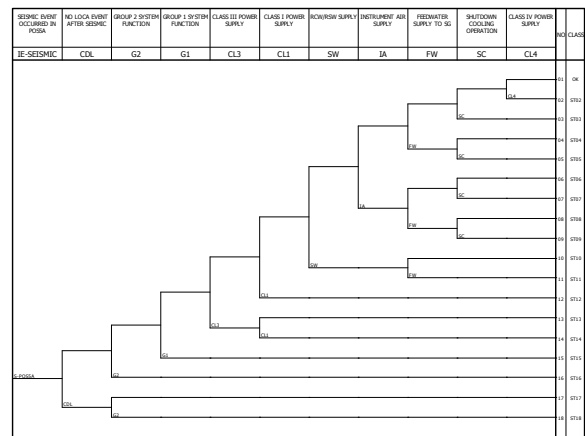


Figure 4. The primary seismic event tree for Wolsong NPP Unit 1

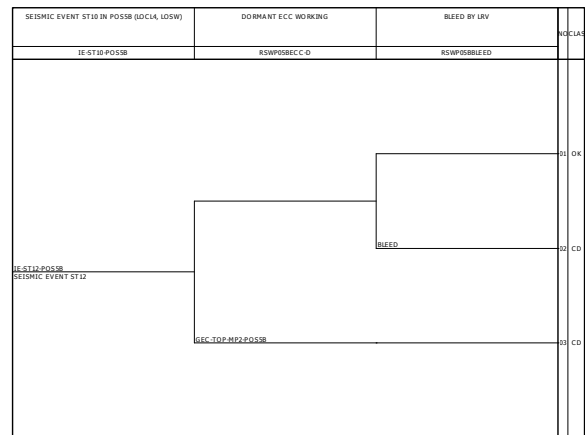


Figure 5. The secondary seismic event tree(ST12, LOCL4 with LOCL3) which considers an additional feed and bleed operation during LPSD mid-loop operation for Wolsong NPP Unit 2,3,4

2.5 Results

The calculated CDFs show that the frequencies of core damage for Wolsong NPP Unit 1 and Unit 2,3,4 are reduced by 37.2% and 34.45% respectively, when the feed and bleed operation has been considered in this study. Also, the frequency of core damage caused by seismic events is reduced by 51.26% for Wolsong NPP Unit 2,3,4.

3. Conclusions

For the domestic CANDU NPP, the feed and bleed operation using DCT over-pressure protection valves has been incorporated as an additional measure to mitigate the consequences during LPSD mid-loop operation. Since LOCL4 with LOCL3 is considered to be the event with highest frequency among all initial events, the effect of the feed and bleed operation on the safety of Nuclear Power Plant has been evaluated using PSA methodology.

Although it is the highly unlikely for the existing the bleed line with DCT level control valves and isolation valve to fail to function, the feed and bleed operation using DCT over-pressure protection valves could improve the safety of CANDU NPP significantly.

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