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The Power pulse and Thermal-hydraulic Response in Large LOCA for CANDU NPP

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1. Introduction

Large LOCA is typically limiting design basis accident in CANDU plants in terms of discharged coolant inventory and the fuel failure. In general, void in CANDU plant give positive effect on the core reactivity. Due to the positive void reactivity, Large LOCA induces very rapid increase of void and power within 5 sends from the start of break which is called power pulse. The amount of power pulse is dependent on the break size and location. Usually break size much larger than feeder size is called large break LOCA. Here the effect of break location and break size in Large LOCA on the thermal hydraulic behavior is analyzed.

2. Analysis Methods

Large LOCA analysis needs feedback from both physics and thermal-hydraulics. The break in large LOCA induces void from rapidly discharged coolant and the void make core power increase due to the positive void reactivity. Increased power make more void in the channel. These feedback effects keep increasing both void and power until shutdown system tripped. These feedback effects are modeled by external coupling calculation between physics and thermal-hydraulics. Physics calculation is performed with WIMS based RFSP and thermal-hydraulics is performed with CATHENA. Coupling calculation between RFSP and CATHENA is performed with perl script.

2.1. Power pulse

It is known that power pulse calculated with PPV was not accurate and conservative. Validation of WIMS on void reactivity is recently performed and it is known that WIMS is more robust and accurate in terms of methodology and uncertainty quantification. Fuel cross section table is generated considering wide range of void amount. RFSP model based on WIMS is made and for the transient calculation CERBERUS model is used for coupling calculation with CATHENA.

Table 1 Core operation parameters

Parameters		Value
Moderator purity(wt%)		99.833
Coolant purity(wt%)		99.0
Moderator poison(ppmB)	pu-peak/eq	6.192/3.611
Moderator tempature(℃)		73
Min. margin to Trip(%)		3.0
Initial side to side flux tilt (%)		4.0

CATHENA steady state are made as shown in Table 2. The power pulses for three different break positions such as RIH, ROH, PS are generated as shown in Figure 1. The break size for each break positons are chosen such that sheath temperature is known to be most limiting. The break sizes for RIH, ROH and PS are 40%, 100% and 50% respectively. Power pulse for RIH and PS break positions are shown to be much greater than that of ROH break position. Trip is assumed to occur at second trip which is high log-rate trip. The trip time for RIH 40%, ROH 100% and PS 50% breaks are 0.40s, 0.47s and 0.83s after break respectively.

Table 2 Steady state value at 103% for eq. core

Parameters		Value
Outlet head pressure (MPa(a))	ROH 1	10.013
	ROH 3	10.014
	ROH 5	10.011
	ROH 7	10.016
Inlet head pressure (MPa(a))	RIH 2	11.175
	RIH 4	11.173
	RIH 6	11.174
	RIH 8	11.182
S/G drum pressure (MPa(a))		4.7
Inlet coolant temperature (℃)		267
Outlet coolant temperature (℃)		310
Core flow per pass (kg/s)		1,970
Pressurizer level (m)		12.471

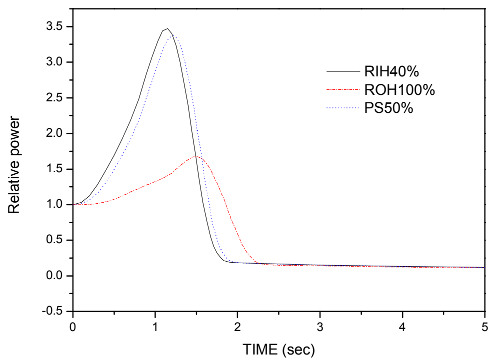

Figure 1 Power pulse for three different break locations

2.2. Thermal-hydraulic behavior

2.2.1 Void generation

The power pulse for ROH 100% break is much smaller than that for RIH 40% and PS 50%. Void generation rate for ROH 100% is much slower than RIH and PS break position as shown in Figure 2. At around 0.5 s after break, the amount of void in RIH and PS break cases are more than 4 times than that of ROH break case. The power pulse for RIH and PS is much greater than ROH in the first 5 second after break.

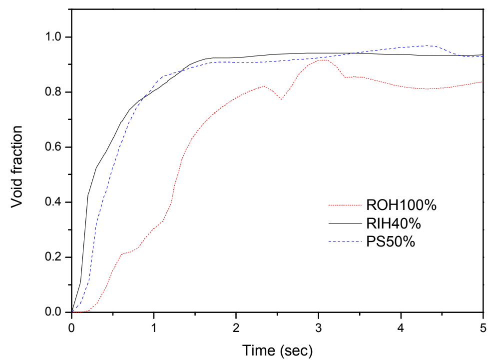

Figure 2 Void for three different break positions

2.2.2 Coolant flow

The coolant pass affected by break are called critical pass. The critical pass flow for three break cases are shown in Figure 3. The flow direction for RIH and PS break cases are revered as soon as break occur and total flow is reduced very fast to less than 250 kg/s within 1 sec whereas the flow direction for ROH break cases is not changed and the amount of flow is reduced much slower rate than RIH and PS.

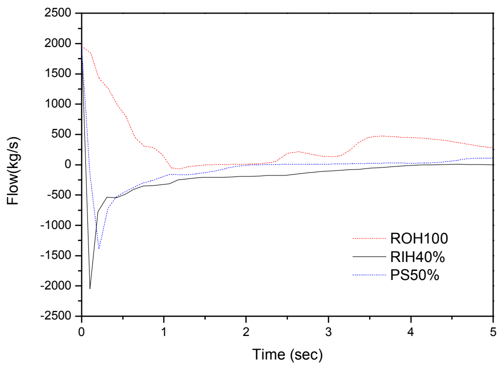

Figure 3 Critical pass flow

2.2.3 Fuel temperature

The fuel temperature is critical parameter for fuel integrity assessment. Maximum fuel sheath temperature for RIH40% break is around 1108℃ at 12sec after break whereas 996℃ at around 88 sec for ROH 100% break as shown in Figure 4. For ROH break cases it is shown that due to the low flow in the long term, fuel sheath temperature is increasing until medium pressure ECC is injected.

Cases	Max. Fuel sheath temp(℃)	Time (sec)
RIH 40%	1108	12.0
PS 50%	1064	15.3
ROH100%	994	88.8

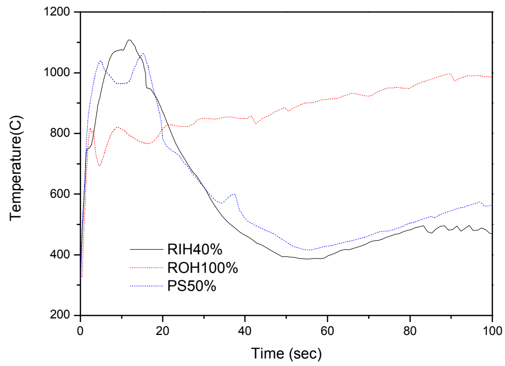

Figure 4 Fuel sheath temperature behavior

3. Results

The power pulse and thermal-hydraulic behavior for RIH, ROH and PS break position is examined for loss of large LOCA. Power pulse and fuel temperature are shown to be the highest for RIH 40% break. In terms of fuel integrity, RIH 40% break is the most limiting case. Though the amount of discharged coolant flow is greater for ROH 100% break, the fuel sheath temperature is much lower because the coolant flow is maintained during the power pulse phase (~5 sec from break). The power pulse and thermal-hydraulic analysis for the entire range of break spectrum will be further developed.

REFERENCES

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