Root-cause Investigation for No Setback Initiation at Liquid Zone Control Unit Perturbation in CANDU6 Reactor

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1. Introduction

Liquid zone control system (LZCS) is one of the indigenous systems in CANDU type reactor for reactor reactivity control. The LZCS is filled with light water and used to provide a continuous fine control of the reactivity and the reactor power level. This system is also designed to accomplish spatial control of the power distribution, automatically, which prevents xenon-induced power oscillations. As the tilt control term is phased out, it is replaced by a level control term, which tends to drive the individual zone levels towards the average level of all the zones. The locations of the LZCs in the vertical direction are shown schematically in Fig. 1[1].

Occasionally the LZCS has some perturbations such as zone oscillation, flooding, draining, etc. At that time power distribution will be tort, and it cannot be controlled without recovering the function of LZCS. If spatial zone power is not stabilize and regional overpower will be increased, then regional overpower protection (ROPT) system will work to protect fuel dryout regionally. Most of CANDU reactors have been experienced these events. Generally setback or stepback conditions are on when variables of spatial control off, high zone power, etc. are reached to the initiating conditions before ROP trip [1] [2]. But the condition of setback or stepback is not initiated before ROP trip sometime. In this study the root-causes for this event are investigated, and the impact assessment is performed by physics computational modeling.

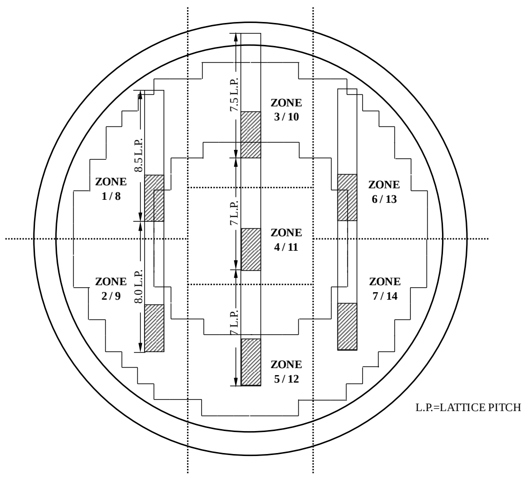

Fig. 1 Locations of the LZCs

2. Perturbation Modeling and Results

In this section typical LZC perturbation case will be modeled, and relative neutron flux will be reviewed at each zone detector flux and ROP detector flux near liquid zone control unit (LZCU) in order to investigate detectors flux behavior by varying liquid zone water level.

2.1 LZC Perturbation Modeling

To evaluate the neutron flux of zone detector and ROP detector at abnormal LZC condition, perturbation models were simulated by WIMS/RFSP [3]. Liquid zone drain cases are appropriate to examine neutron flux perturbation regionally. The initial condition for zone drain is steady-state condition at 80% of average zone level (AVZL). Each zone water level will be drained by 10% to 0%. Detector response will be reviewed for zone 01~07.

2.2 Results for Zone and ROP Detector Response

Before comparing zone detector and ROP detector readings at liquid zone abnormal condition, responses of zone detectors were reviewed as shown in Fig 2.

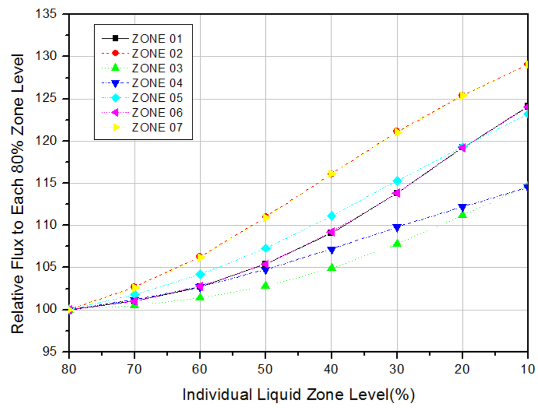

Fig. 2 Response of Each Zone Detector for Zone Drain

As shown in Fig 2, the responses of liquid zone drain are categorized by 3 types. It is caused by the location of LZC in reactor core such as top or bottom as shown in Fig 1. Flux readings of liquid zone 03 and 04 are very gradually increasing than other zones when draining liquid zone water level. In case of zone 04, flux variation is impacted by near control devices (adjusters in the inner core). But the response of zone 03 is happened due to LZC installed position. So we focused on the zone 1, 3, and 6 to compare the detector flux readings. Fig 3 shows liquid zone 1, 3, and 6 detectors and the nearest ROP detectors at LZC. In addition, zone power was reviewed to check zone detector response and zone power trend for zone 01, 03, and 06. Zone power trend for LZC drain event is similar with zone detector reading relatively as shown in Fig. 4.

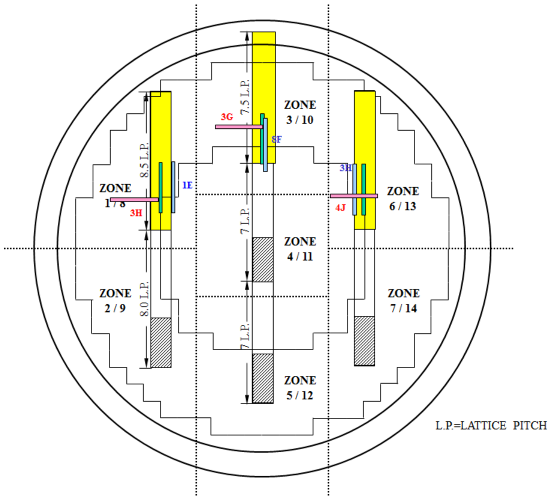

Fig. 3. LZC and ROP detectors at Zone 01, 03, and 06

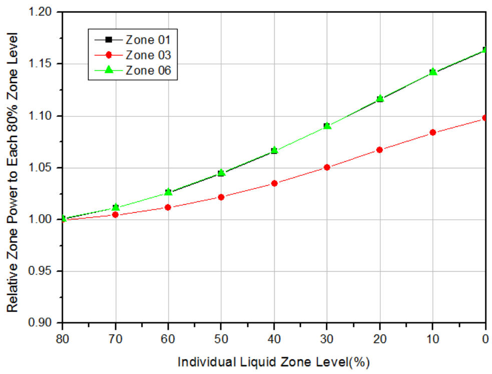

Fig. 4. Zone Power at zone 01, 03, and 06

Fig 5, 6, and 7 show the relative flux readings of zone and ROP detectors by LZC water level draining at zone 01, 03, and 06, respectively. Zone detector flux readings are over 5% higher than near ROP detectors at zone 01 and 06. Different with zone 01 and 06, zone 03 detector reading is reversed into ROP detector (SDS#2 3G) reading at water level 40% of zone 03. Generically ROP trip setpoint is designed to 122%FP for new plant condition in CANDU 6 reactor. So ROP trip is not likely to occur when liquid zone 03 is perturbated. But ROP trip setpoint is decreasing by reactor aging. If liquid zone 03 has a severe perturbation such as draining or high zone level oscillation at aged condition, then ROP detectors at near zone 03 will be more sensitive to overpower. Therefore, ROP trip signal could be occurred before initiating setback condition by spatial control off variable when zone perturbation is occurred in only zone 03. Note setback and stepback are initiated to notify and clear abnormal operating condition avoiding unanticipated reactor trip. Even though setback or stepback are not initiated before reactor trip, reactor is still safe by trip signal.

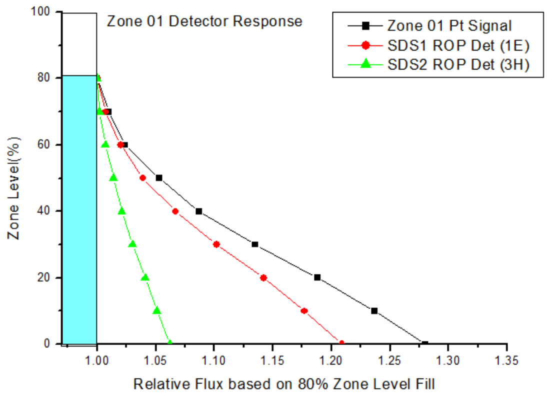

Fig. 4. LZC Pt. and ROP detectors response at zone 01

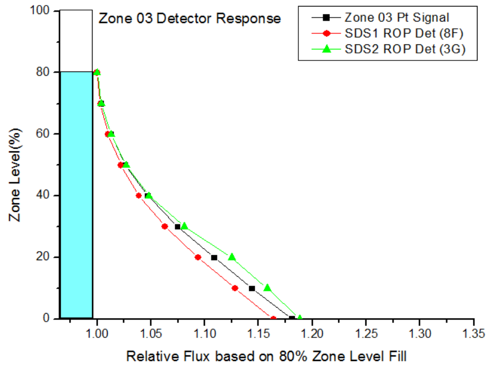

Fig. 5. LZC Pt. and ROP detectors response at zone 03

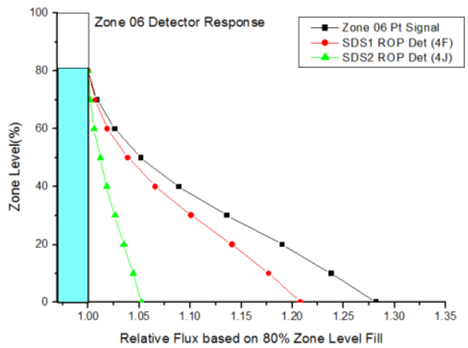

Fig. 6. LZC Pt. and ROP detectors response at zone 06

3. Conclusions

To investigate the root-cause of ROP trip before initiating setback at abnormal operating condition, some LZC perturbation models were simulated and investigated the neutron flux readings of zone detector and ROP detector.

Two root-causes were founded. The first, flux variation by water level change is more gradual than other zones due to design characteristics in zone 03. The second, ROP detector (SDS#2 3G) in the near zone 03 is very sensitive below 40% of water level due to ROP detector installed position. Even though setback is initiated earlier than ROP trip in case of zone 03 perturbation, ROP trip will be occurred because power decreasing rate is very slow(0.1%/sec) on setback condition. The important point is if reactor trip is working well, reactor is still safe whether setback initiate or not.

REFERENCES

[1] 86-63729-PS-104, "Program Specification Reactor Power Setbacks", AECL, December 1976.
[2] 86-63729-PS-112, "Program Specification Reactor Power Stepbacks", AECL, August 1977.
[3] S. R. Douglas, "WIMS-IST Release 2.5d Users' Manual", COG Report COG-94-052 / AECL Report RC-1176/FFC-RRP-299, 2000.
[4] P. Schwanke and A. Ho, "RFSP 3.5 User's Manual", COG Report, SQAD-12-5022/147-117360-COG-002, 2012.