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Application of Flux Tilt Parameters to Support Regional Overpower Protection Trip Coverage for a CANDU®-6 Reactor

by

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Currently at the Point Lepreau Generating Station (PLGS), the on-line Reactor Regulating Monitoring (RRM) module supports a number of functions that evaluate various types of flux tilt within the reactor core. A scoping study was performed to assess operating limits for five RRM flux tilt functions that would support ROP trip coverage: (i) maximum, axially-averaged, non-central zone flux deviations (NC ZDROP); (ii) excess side-to-side flux tilt (SSTILT); (iii) excess top-to-bottom flux tilt (TBTILT); (iv) excess radial tilt (RDTILT), and; (v) excess axial flux tilt (MAXTLT). These functions were considered because they have been found to be often associated with many of the more limiting ROPT cases. The NC ZDROP parameter has been applied at PLGS since 1993 as a criterion for the selection of ROPT hand-switch selection (i.e. selection of pre-defined ROP trip setpoints). This paper presents additional verification results for this parameter. The expected benefit of the study was an optional increase in ROP trip setpoints for normal operations (HSP-1) after removing these more-limiting flux shapes from the HSP-1 case set.

Over 500 simulated off-nominal configurations and flux shapes were considered. Simulation data were generated by AECL [1]. The database included liquid zone controller drain events, bulk xenon transients, zone-induced transients, reactor startups, adjuster shim events, "Stepback" and "Setback" events, and moderator drain events. Those events requiring the selection of a more-limiting set of ROP trip setpoints (e.g. "HSP-2") were excluded from the study. Therefore, all 500+ cases were initially in the HSP-1 case set. AECL also provided ROPT minimum trip confidence data for all 500+ cases and identified the twenty-six most-limiting cases [1].

Flux tilts and deviations were calculated using the simulated measures of: (i) zone-integrated fluxes supplied by the Reactor Fuelling Simulation Program (RFSP); (ii) zone-integrated fluxes calculated by the off-line Flux-Mapping program, which performs the same calculations as the on-line Flux-Mapping Program, and; (iii) un-calibrated Reactor Regulating System zone-platinum detector signals.

ROP trip confidence data were plotted against each flux tilt function. Correlations were observed between the twenty-six most-limiting off-nominal cases and three of the flux tilt parameters (NC ZDROP, RDTILT, MAXTLT). It was found that the more-limiting ROP

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cases were characteristic of larger radial tilts or larger zone flux deviations (i.e. NC ZDROP). Figures 1 and 2 shows the relationships between ROP trip confidence (26 most-limiting cases) and the RFSP-calculated measure of excess radial tilt and NC ZDROP, respectively. Case numbers have been printed adjacent to those data points corresponding to radial tilts above 15 % to permit identification of the different cases.

When all three simulated data sets were considered, suitable operating limits were selected for the three flux tilt parameters. Table 1 identifies those ROP cases that would be "covered" by each flux tilt parameter, assuming a specific operating limit. Upon inspection, case 282 is the most limiting case. With an alarm limit set at 15 % for non-central, axially-averaged zone flux deviation (NC ZDROP) and an alarm limit set at 7 % for excess radial tilt (RDTILT), the reactor operator would be alerted for all subsequent limiting-ROP cases down to #319 in Table 1. Removing these cases from the HSP-1 case set may permit an optional increase in ROP trip setpoint of about 3 %. It was found that the measure of maximum excess axial tilt provided a redundant coverage when compared against the RDTILT and NC ZDROP parameters.

The paper will also discuss an assessment of the uncertainty in each flux tilt parameter and the relationship between the margin-to-sheath dryout as a function of each flux tilt or zone flux deviation.

This scoping study was based on preliminary source data [1]. The results and conclusions of this study may change without notice should the source data be altered.

Reference:

1. M.R. Soulard, G.D. Harvel, J. Pitre, and W. Hartmann, "Impact of Heat Transport System Ageing – Critical Channel Powers and ROPT Setpoints Part 2: Point Lepreau (Draft)", AECL unpublished data, 1999 August.

Table 1: Flux Tilt Minimum Values of RFSP, FLUXMAP, and Piu Data for 26 Most Limiting Cases based on PLGS HSP-1 Case Set

Case No.	Minimum Trip Confidence (ROVER-2)	Minimum NC ZDROP (%)	NC ZDROP greater than 15%	Minimum RDTILT (%)	RDTILT greater than 7%	Minimum MAXTLT (%)	MAXTLT greater than 12%
282	0.980007	-0.08%		19.51%	✓	0.10%	
735	0.985097	30.00%	✓	-1.41%		0.11%	
734	0.986362	28.91%	✓	-1.50%		0.12%	
630	0.986474	18.50%	✓	4.38%		19.80%	✓
152	0.987789	0.63%		15.45%	✓	0.07%	
736	0.988261	28.39%	✓	-1.14%		0.09%	
249	0.99008	23.81%	✓	11.14%	✓	2.64%	
733	0.991002	25.49%	✓	-1.44%		0.13%	
632	0.991103	17.93%	✓	4.27%		25.25%	✓
694	0.991295	-1.09%		33.60%	✓	0.11%	
742	0.992041	29.88%	✓	-1.39%		0.05%	
222	0.992464	3.30%		19.13%	✓	0.06%	
741	0.992775	28.72%	✓	-1.49%		0.13%	
246	0.993402	11.14%		9.38%	✓	7.45%	
288	0.993677	2.49%		15.26%	✓	1.00%	
743	0.993792	28.30%	✓	-1.13%		0.10%	
284	0.993999	0.81%		19.32%	✓	4.23%	
737	0.994225	23.24%	✓	-0.75%		0.12%	
149	0.994692	20.85%	✓	-0.21%		0.02%	
248	0.994743	11.71%		11.06%	✓	7.52%	
148	0.994979	20.48%	✓	-0.28%		0.03%	
305	0.995034	-0.20%		13.63%	✓	6.17%	
319	0.995298	9.67%		6.87%		0.22%	
740	0.995386	25.24%	✓	-1.43%		0.09%	
290	0.995476	3.89%		11.78%	✓	6.16%	
50	0.995759	7.36%		-2.51%		8.77%	

Figure 1: 26 Most Limiting Cases – PLGS HSP-1 Case Set - ROP Trip Confidence vs. Maximum Non-Central Zone Flux Deviation (RRM Parameter: ZDROP) – RFSP Data

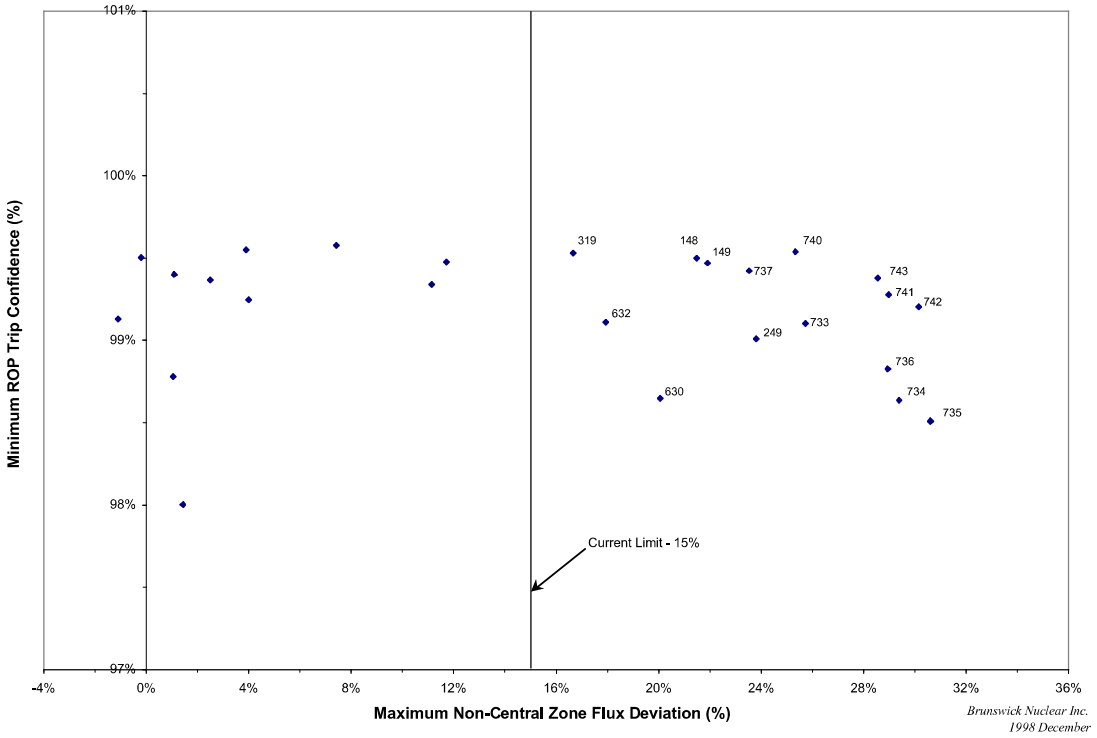

Figure 2: 26 Most Limiting Cases – PLGS HSP-1 Case Set - ROP Trip Confidence vs. Excess Radial Tilt (RRM Parameter: RDTILT) – RFSP Data