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HSP Rule Optimization of Regional Overpower Protection System for Wolsong NPP

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1. Introduction

In CANDU reactors, the Regional Overpower Protection Trip (ROPT) systems protect the reactor against overpowers in the reactor fuel, whether these are due to localized peaking within the core or to a general increase in the core power levels. The ROPT systems each have detectors distributed about the core to ensure coverage of the local flux and power peaks that could arise due to maneuvering, or to normal or abnormal combinations of reactivity devices inserted or withdrawn. For this purpose, the ROPT setpoint is calculated using design and non-design basis flux shapes for slow loss of regulation (SLOR), critical channel power (CCP) related flux shapes, and uncertainties of detector and thermal hydraulic conditions. However, these flux shapes were generated on the basis of the operating procedure for the Gentily-2 or Point Lepreau nuclear power plants in 1995. In general, some of these flux shapes are thought to match with the operation of the Wolsong nuclear power plant, but some have aspects that need to be improved.

In this study, the re-classification of flux shapes has been performed to match them with the operation of the Wolsong NPP.

2. Optimization of HSP Rule Methods

2.1 Assumptions and Data for ROPT Design

The flux-shapes to be used in the ROPT analysis fall into three categories [1]:

1) Design-Basis

These flux-shapes determine the coverage characteristics and capabilities of the ROPT designs during normal operating conditions (i.e. with Hand Switch Position 1 or HSP-1).

2) “Test” Cases

These flux-shapes are used to test claimed characteristics of the ROPT coverage – for example, the robustness of its coverage of device configurations not in the design-basis set that are expected to be covered with HSP-1.

3) Special Conditions

Additional flux-shapes may be simulated to assess ROPT coverage when operating in various special conditions – for example:

- Abnormal device configuration
- Two pump operation (HSP-3)
- Long-term operation with off-nominal device configuration
- Slow moderator drain

Tables 1 and 2 show the design and non-design flux shape categories, respectively.

Table 1
Design-Basis Flux Shapes for ROP Evaluation

• Design-Basis Case Set : 232 cases	
– Steady-States	9
– Zone Drains	56
– Single Adjuster Full and Half Withdrawn	42
– MCAs in Banks	16
– Zone-Induced Tilts	20
– Harmonic Tilts	10
– Startup after Short Shutdown	18
– Delayed Startup	19
– Startup after Long Shutdown	4
– Stepback to 60%FP	11
– Adjuster Shim	20
– Adjuster Banks Half-out	7

Table 2
Non-Design-Basis Flux Shapes for ROP Evaluation

• Non-Design-Basis Cases : 692 cases	
– Additional Analyzed Cases : 451	
• NSC(No Spatial Control) Cases (Startup, shim, single ADJ, Zones)	42
• “Robustness” test cases (SORs, manual startup)	74
• HSP-2 setpoint cases (Co-axial adjusters, zone control Failure)	22
• Combined configurations (Operating configuration + D/B perturbations)	267
• Moderator Drain	46
– Follow-up Non-D/B Cases : 241	
• Moderator Poison Added	27
• Adjuster Location Uncertainty Study	11
• Gentily-2 Post-simulation Cases	7
• Side-to-side Tilt Coverage Limits	29
• Miscellaneous Additional Combined Configurations	39
• Shim + Loss of Fuelling	15
• Single-rod Startups	32
• HSP-3 Setpoints (One Pump per Loop)	52
• Startup with MCAs Inserted	29

2.2 Current HSP Changing Rule for ROPT Design

Initial HSP-1(normal operation) ROPT setpoint was determined as evaluation to meet 98% trip probability for a set of 232 design-basis cases . The reduction in setpoints required for HSP-2 was determined statistically from various cases that were missed by significant margins from the normal HSP-1 setpoints. The reduction for HSP-2 was based on the average miss plus twice the standard deviation of the misses. Therefore, some cases that were not covered by HSP-1 setpoints were put to the HSP-2 category. Data on these cases are shown in Table 3. The HSP-3 ROPT setpoints were determined for protection on a 98% 2-out-of-2 trip probability, for flux-shapes that could arise in symmetric two-pump operation. The HSP-3 cases are obviously classified by pump operating status.

Therefore, the current HSP changing rule for SLORC (Slow Loss Of Regulation Condition) is divided into three positions, as follows;

- HSP-1(Normal operation) : Normal Operation
- HSP-2(Abnormal operation) : Not covered by HSP-1, except HSP-3
- HSP-3(Two Pump operation) : One pump operation in a loop

Flux shapes, including the HSP-2 categories, should be periodically monitored by the operator and limited by an installation of an alarm system.

2.3 Basic Concept of HSP changing Rule Optimization

The HSP changing rule for HSP-3 is clear for the operator. As can be seen in Table 3, the HSP-2 changing rule is very complicated for the operator to make a decision, and not matches with operation procedure in Wolsong NPP. Therefore, the HSP changing rule should be well re-categorized and fitted as an operation rule for the Wolsong NPP.

The basic concept of re-categorization is as follows: First, the standard of classification to change the HSP as the core condition should be simple and obvious for the operator to perceive. Second, an annunciation system for the operator to change the HSP should be installed. Finally, operating procedures should be prepared to change the HSP. Therefore, five action items were drawn up, as below.

- One Pump per Loop removed from operation
- "Startup after Short Shutdown" cases move to HSP-3
- "MCA/SOR Out or Stuck" operation moves to HSP-3
- "Adjuster Out or Stuck" operation moves to HSP-2
- Enhancement of "ZDAA" Alarm Limit (7% and 10%)

On the basis of the five action items, re-categorization for the current 926 flux shapes has been performed and is summarized in Figure 1.

Table 3
Comparison of ROP Evaluation Flux Shapes

	Current	New Rule
HSP-1	Below ZDAAi≤15%	ZDAAi ≤7%
HSP-2	ZDAAi > 15%	7% < ZDAAi ≤ 10%
	3 Co-axial ADJ's out (AAs'-3,10,17 or 6,13,20)	ADJ Move Out
	3 MCAs inserted and more than two banks of AA	
	Five or more AA Banks out and MCA Inserted	
HSP-3	Two Pump Operation	10% < ZDAAi
		SOR Movement
		MCA Movement
		Startup After Short Shutdown

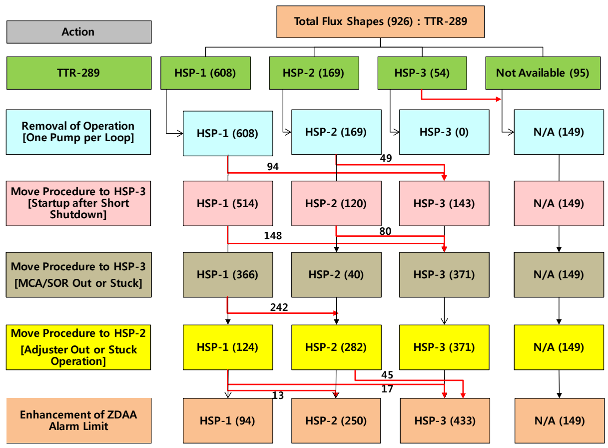

Figure 1
Categorization of ROP Evaluation Flux Shapes

3. Results

The reactor configurations with adjuster banks out and SOR/MCA out will no longer be considered as normal operating conditions at the Wolsong NPP. The implementation of clear alarms and procedures in the control room directs the operator to turn the handswitches to position HSP-2 or -3, which have lower setpoints. Moreover, the HSP-2 and -3 alarm limit of axially averaged zonal deviation (ZDAA) is divided into two steps, of 7% and 10%, respectively.

Since these flux shapes were limited in previous ROP analyses, about a 5% ROP margin will be recovered after removing these flux shapes from HSP-1.

REFERENCES

1. F.A.R. Laratta, G.K.J. Gomes, C.M. Bailey, "Design and Assessment of the Replacement ROPT Systems for Wolsong 1", TTR 289 Part 1 (W1), August 1995