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Evaluation of ROP Margin Effectiveness by REFORM Region

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1. INTRODUCTION

In CANDU reactors, the Regional Overpower Protection Trip (ROPT) system protects the reactor against overpowers in the reactor fuel, whether due to localized peaking within the core or a general increase in core power levels. Due to Primary Heat-Transport System (PHTS) aging the ROP trip setpoint is decreasing over time. Reductions in ROP trip setpoints are required to maintain the required trip-probability and ROP trip effectiveness, and results in a decrease of the ROP margin-to-trip during normal operation. In addition, full power operation can be threatened. In this point, to recover ROPT margin, channel power needs to be redistributed. ROPT setpoint is very conservative in normal operation because distortion of regional overpower is over 1.2 times as nominal power in slow loss of regulation (SLOR). Channel power ratio (CPR) is enough low except the limiting channel of which worst case of design basis flux shape. If the outer channel power is slightly increased and the inner is decreased, ROPT margin is more effective. In this study, we try to redistribute the CPPF region by power level. Therefore we intend to minimize the change of channel power and maximize the reformed ROP margin. In Section 2, reform methodology and computational result is introduced for the established CPPF region. And then reformed ROP margin will be evaluated for the changed reform region.

2. REFORM OF CHANNEL POWER

2.1 Reform Methodology

The REFORM process modifies the reference channel power distribution in order to optimize the ROP operating margins. The application of REFORM factors to the channel power map tunes the overall power shape of the core to enhance the ROP margin. This power shape may be used as a target power for refueling. REFORM adjusts the critical power ratio in each channel in the core so that probabilistic ROP coverage is uniform throughout the core and is maximized over all limiting ROP cases. To accomplish this power shape, some channel power is adjusted to have power shape such that channels for which the limiting ROP case has lower trip probability will have higher trip probability. Typically high powers in the center of core are redistributed to the outer channels.
Equation to calculate the trip setpoint is given by equation (1).

$$TSP(j_p) \le D_0 \frac{\Phi(k, j_{p,i})}{\left[\dfrac{CP(k,m)}{CP_0(m)}\right]} \left(\frac{CCP(k,m)}{CP_{ref}(k,m)}\right)_{Lim} \frac{1}{1+EA} \quad (1)$$

where
$\Phi(k,j_{p,i})$: Normalized detector reading for limiting detector,
CCP : Critical channel power,
CP : Channel power,
$TSP(j_{p,i})$: Detector trip setpoint,
EA : Error allowance, and
$R_{ref}(m)$: REFORM factor.

The REFORM factor $R_{ref}(m)$, the factor by which a fuel channel should be modified, is given by equation (2)

$$R_{ref}(m) = \min_k \left\{ \frac{\Phi(k, j_{p,i})}{\alpha TSP(j_{p,i})} \left(\frac{CCP(k,m)}{CP(k,m)}\right)_m \right\} \quad (2)$$

where α is the change value in the detector trip setpoint after the REFORM. Thus the process is iterative: as the detector trip setpoint changes, the REFORM factor for each channel also changes. This process converges to a solution. Then the reformed reference channel powers can be calculated with equation (3)

$$CP_{ref}(m) = R_{ref}(m) \cdot CP_o(m) \quad (3)$$

CPPF and CPR are calculated in the CPPF region only. Also Reform calculation is performed. We redistribute the REFORM Region by channel power level. That region is shown as Figure 4. In this study, we redistribute CPPF region by power level. Also we try to recalculate the reformed channel power and ROP trip setpoint effectiveness.

2.2 Results of Calculation

The REFORM module was performed by ROVER-F[1] code for Wolsong-3 NPP at 2600EFPD using the design basis flux shapes (232 cases)[2]. The nominal and reformed channel power maps were shown as Figure 1 and 2, respectively. Figure 3 shows the difference of two channel power maps. The channel powers in the left and lower core except the CPPF region were increased about 3~10%, and the channel powers of the right and lower core were decreased by the same amount.

Reforming results by various reform regions are shown as Table 1 and Figure 5. It is evaluated effective over 5.2MW power level region. That is similar to CPPF region. The reform region is narrower, the reformed ROP margin is less.

3. CONCLUSION

In this study, the REFORM calculation for a specific burnup stage of Wolsong-3 was performed. The result shows an improvement of ROP margin by about 5%. It is similar to the existing reform calculation. In this study, we can understand that reform of nominal channel power decrease inner core power and increase the outer. If the reform region is made to narrow, reforming is meaningless. Finally the change of reform region is not effective for reformed ROP margin. In the future, we try to adjust the reformed channel power level. And then the optimized reformed channel power distribution for feasible and economic channel power distribution will be considered.

REFERENCES

1. V. Caxaj, "ROVER-F Version 2-04 Manual", AECL Report CW-117390-MAN-003, 20 05 April.
2. F. A. R. L. Laratta, et. al., "Design and Assessment of the Replacement ROPT Systems for Wolsong-1", TTR-289 Part 1 (W1), AECL, Aug. (1995)
3. D. Jenkins, et. Al., "AMAD for Physics Simulations", TDAI-440 Part I , AECL, May (1991)

Table 1. Results as Various Reform Regions

Reform Region	Reformed ROP Margin(%)
CPPF Region	5.41
5.0	6.06
5.2	5.83
5.5	2.18
5.7	2.18
6.0	0.27
6.2	0.03
6.5	0.00

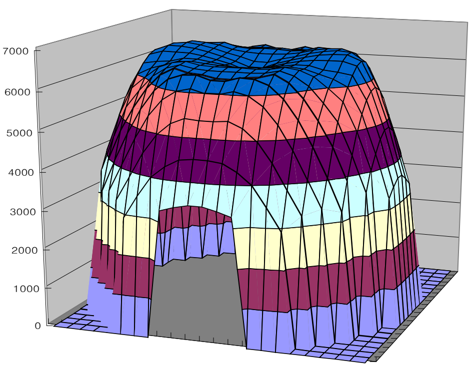

Figure 1. Distribution of Nominal Channel Power

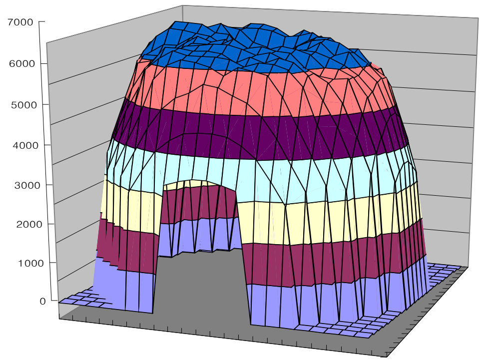

Figure 2. Distribution of Reformed Channel Power

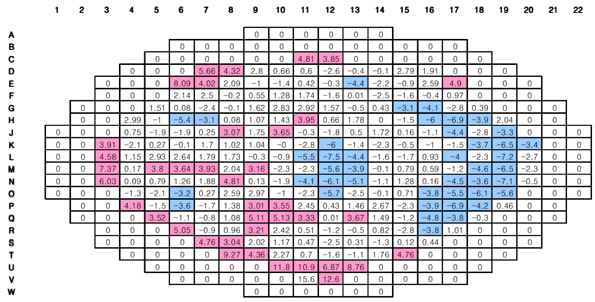

Figure 3. Difference of CP_{ref} from CP_o

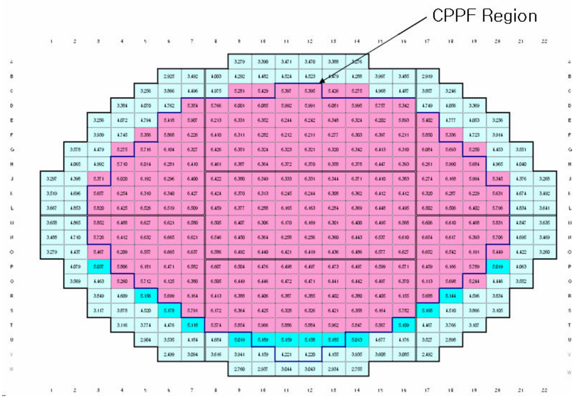

Figure 4. CPPF Region by Power Level

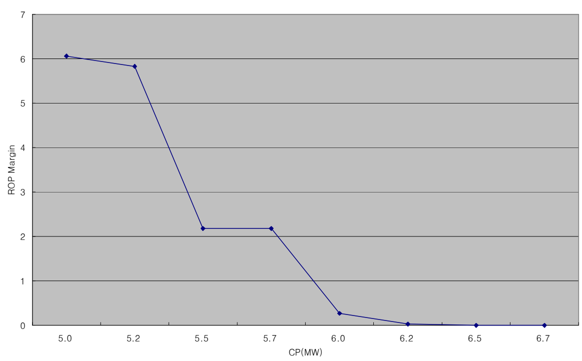

Figure 5. Reformed ROP Margin by CPPF Region