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Evaluation of Channel Power Peaking Factor Region for CANDU6

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1. INTRODUCTION

CPPF (Channel Power Peaking Factor) is an estimate of the maximum nominal channel overpower expressed as a ratio, like ripple, from the reference channel power - 1989 Time Average Model[1].

CPPF is used in detector calibration to establish the required detector readings at power. More specifically, CPPF is the middle of the allowable band (±2%) that the operators maintain the ROP(Regional Overpower Protection) detector readings. This is the only physical aspect relevant for ROP. The calculation is based on an off-line reactor fuelling simulation including the upcoming channels selected for refuelling. A POWER-MAP calculation is made using an updated rippled fundamental, and flux mapping input provides the actual core variations i.e. actual zone level, not foreseen in the simulation. CPPF calculation is limited in the CPPF region. The design of the CPPF region for CANDU 6 reactors was deliberate and it is reviewed periodically by the TAP (Time Average Performance) update procedure. It is recognized that refueling rippled using a reference channel power distribution from a time average RFSP simulation will result in much higher "apparent" ripples in the outer core than the inner core. This is off-set, however, by the still higher level of CPR (critical power ratio) in the outer core even for reactors with power/flow matched feeders. As such, the "effective" ripple for ROP is generally much lower. The criterion of dryout for a fuel channel is neither its channel power nor ripple but its CPR. In this study CPPF region will be re-evaluated and try to optimize for Wolsong-1 NPP.

2. EVALUATION OF CPPF REGION

2.1 Definition and Use of CPPF

In equation (1), D_C (Detector calibration) factor is very important to establish the required detector readings at power. D_C includes calibration factors of physics and thermo-hydraulic condition.

$$D_C = (RA + D_{TC} + D_{TILT}) \times F_{PHT} \times F_C \times F_F \times RP \quad (1)$$

where
Dc is Detector Calibration Factor,
RA is Ripple Allowance,
(RA=CPPF+TAP Correction Factor + Pressure Tube Creep Penalty + Correction Factor by FPD + Correction Factor of Moderator Material),
$\mathbf{D_{TC}}$ is Temperature Correction Factor of Detector,
$\mathbf{D_{TILT}}$ is Correction Factor of Flux Tilt,
$\mathbf{F_{PHT}}$ is PHTS Parameter Correction Factor,
$\mathbf{F_F}$ is Correction Factor of Different Fuel Type, and
RP is Reactor Power

And equation to calculate the power limit is given by equation (2).

$$\text{Power Limit} = \frac{\text{ROPT - 4}}{D_C + 2} \quad (2)$$

where ROPT is the Regional Overpower Trip Setpoint. As previous equations, CPPF value decides the power limit in general. CPPF is calculated as follows, equation (3),

$$CPPF = \frac{CP(m)}{CP_O(m)} \quad (3)$$

where subscript 'O' means the nominal or reference case, and m is a channel number.

2.2 Evaluation of CPPF Region

CPPF and CPR are calculated in the CPPF region only. The CPPF region was initially established using the whole set of design basis flux shapes[2] and a 600 FPD refueling simulation to systematically include all fuel channels which could be CPR limiting and for which the provision of CPPF in detector calibration would be insufficient for coverage. This occurrence was tracked and shown for each flux shape in the old ROVER-F[3] outputs and with an accompanying map showing the offending fuel channels. It means that for a given flux shape, the most limiting channel may be outside the CPPF region, however, the relative reduction in CPR due to fuelling i.e. the limiting unrippled CPR in the inner core divided by the outer channel's rippled CPR is less than CPPF. It means that if an outer fuel channel has an unrippled CPR which is larger than the limiting inner core unrippled CPR and CPPF is never below 1.05. Then outer channel can sustain a ripple of at least 1.05 times of inner and outer unrippled CPR ratio and still be covered by ROP. Nominal and abnormal CPR and is shown by Figure 1 and 2, respectively.

In this study, rippled CPR calculation for four CPPF regions was performed and compared with the results for nominal and abnormal (liquid zone drain case) condition. Four CPPF regions are shown in Figure 3 and Figure 4 shows region wise-CPPF history.

3. EVALUATION RESULTS

The ROP setpoints were evaluated by ROVER-F code using the same inputs but CPPF region only. Detector calibration and power limit calculation were also performed. As shown by Table 1, the wider CPPF region, the larger trip setpoint gains, but the less operating margins. For example, one can get the largest TSP gain in the CPPF region A covering all channels except FARE Zone, but he/she also has to take the largest loss in operational margin. More results for aged CANDU-6 core shown in Table 2. The result has a same tendency to TTR-289. The limiting detectors for case were generally located in the oval type of the CPPF region. 4H, 5G, 1H, 6G, 6H, 5J detectors of SDS#2 have trip probability below 99%.

4. CONCLUSION

In this study, we have performed the trip setpoint for four different CPPF regions. It was evaluated that the larger CPPF region, the more TSP gains, but the less operational margin. For the aged core, the same trend was observed. The limiting detector for case was generally located in the oval type of the CPPF region. From the feasibility study it is concluded that simple regional widening is no effect on optimizing CPPF region. Therefore, to find a way for optimal CPPF region compromising TSP gain and operational margin, we are going to study channel-wise power effects on the detector locations.

REFERENCES

1. D.Jenkins, et. Al., “ AMAD for Physics Simulations”, TDAI-440 Part I , AECL, May (1991)
2. V. Caxaj, “ROVER-F Version 2-04 Manual”, AECL Report CW-117390-MAN-003, 2005 April.
3. 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)

Table 1. Results as Various CPPF Region(TTR-289)

	Avg. CPPF	Difference of T. S.*	Dc	Power Limit
CPPF Region	1.0619	-	1.0809	1.0900
Region A	1.0668	0.0054	1.0859	1.0851
Region B	1.0599	-0.0025	1.0789	1.0920
Region C	1.0581	-0.0048	1.0776	1.0933
Region D	1.0575	-0.0055	1.0765	1.0944

* T.S. : Trip Setpoint

Table 2. Results as Various CPPF Region(6585EFPD)

	Avg. CPPF	Difference of T. S.	Dc	Power Limit
CPPF Region	1.0619	-	1.0772	0.9219
Region A	1.0668	0.0027	1.0859	0.9178
Region B	1.0599	-0.0042	1.0789	0.9236
Region C	1.0581	-0.0062	1.0776	0.9252
Region D	1.0575	-0.0067	1.0765	0.9257

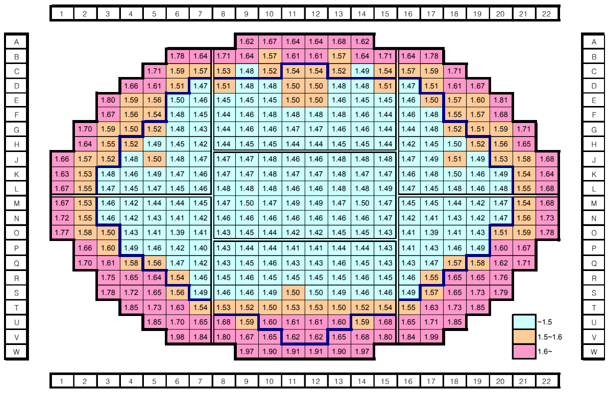

Figure 1. Nominal CPR Distribution of for Wolsong-1

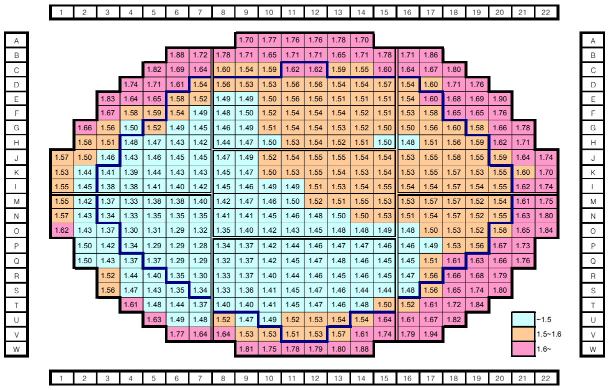

Figure 2. Case039 CPR Distribution of for Wolsong-1

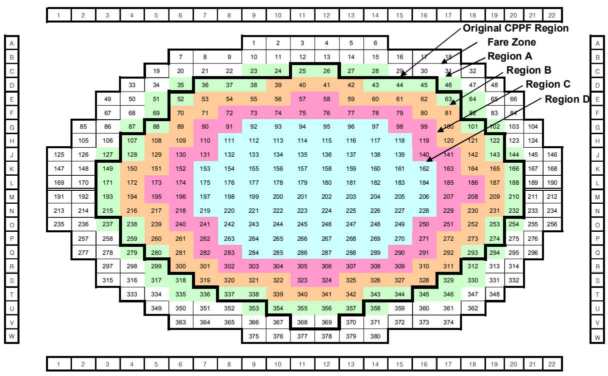

Figure 3. Regions for Evaluation of Rippled CPR

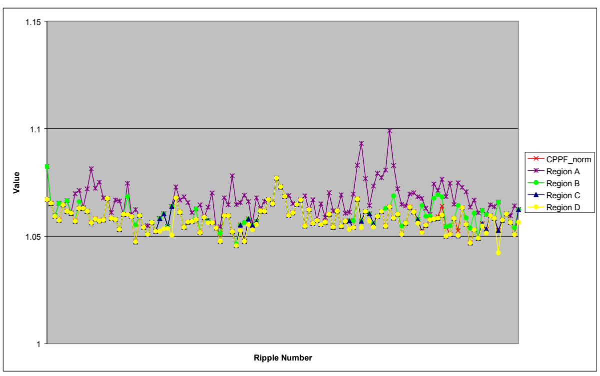

Figure 4. CPPFs by Region