# CCP Sensitivity Analysis by Variation of Thermal-Hydraulic Parameters for Wolsong Unit 2 Reactor

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## 1. Introduction

ROPT(Regional Overpower Protection Trip) setpoint is decreasing by reduction of CCP(Critical Channel Power) due to aging effects such as pressure tube diametric creep. For this reason, Wolsong-2 has been operating less than 100% reactor power due to the result of ROPT setpoint evaluation[1][2]. Typically CCP for ROPT setpoint calculation is derived at 100% PHTS(Primary Heat Transport System) boundary conditions - inlet header temperature, header to header differential pressure and outlet header pressure. Therefore we have to calculate the estimated boundary conditions at 100% power and assess the inherent uncertainty of the thermal-hydraulic model. The sensitivity studies by varying thermal-hydraulic parameters for CCP calculation were evaluated for Wolsong unit 2 reactor.

## 2. Modeling and Results

In this section computational tools and model will be introduced and the results is described for sensitivity analysis for CANDU 6 reactor PHTS.

### *2.1 Analysis Tools*

The NUCIRC[3][5]/NUPREP[4] 2.3.1.2 code systems were used for most of sensitivity analyses.

The computer program, NUPREP[4] 2.3.1.2, is a data pre-processor which is used to prepare the input data into the sequence required by the input stream of NUCIRC 2.3.1.2. NUPREP reads the specific input data (e.g., inlet/outlet feeder geometries, orifice data, bundle/channel power) for all the channels from permanent files and other common channel data prepared by the user, then sorts the data into the input stream required by NUCIRC for each channel.

NUCIRC[3] is a steady-state thermal-hydraulic code used by designers and analysts to examine the behavior of the HTS of a CANDU® nuclear reactor over a wide range of single-phase and two-phase operating conditions [5]. This code can predict pressure, channel flow, temperature and quality at any location of the primary heat transport system, and determine critical channel power ratios for both dryout and melting during overpower for any required number of channels, etc.

### *2.2. Modeling Conditions*

Wolsong-2 PHTS data are acquired and modeled at 80% and 93% power condition. And thermal-hydraulic boundary conditions of 100% power to calculate CCP were estimated. Hence the major parameters of thermal-hydraulic model to impact to CCP are pressure tube roughness, orifice degradation factor and SG fouling factor, etc. For sensitivity analyses, parameters such as pressure tube roughness, Orifice degradation factor, SG fouling factor, SG tube roughness were varied by 5%, 10%, 20%, and 30%, respectively.

### *2.3 Results of Sensitivity Calculation*

Table I shows the results of sensitivity calculation. In spite of excessive thermal-hydraulic parameter variation, the %CCP sensitivities for $T_{RIH}$ and $DP_{HH}$ were maintained constant, and the linearity of sensitivities was also valid as shown in Fig 1 to Fig 8. Moreover the difference of ROPT penalty for changing sensitivity is only ~0.005% for $T_{RIH}$ and ~0.026% for $DP_{HH}$. These differences are much more than the error which may be occurred by designer change.

Therefore the uncertainty in the PHTS thermal-hydraulic model at 100% power is negligible considering the plant procedure of thermal-hydraulic boundary conditions penalty.

Table I. Results of Sensitivity Calculation for Thermal-hydraulic Parameters change

| | | Reference model | PT Roughness 10% | PT Roughness 30% | Orifice 10% | Orifice 30% | SG Fouling 3% | SG Fouling 20% | SG Roughness 10% | SG Roughness 30% |
|---|---|---|---|---|---|---|---|---|---|---|
| $T_{RIH}$ | Avg.(℃) | 264.7 | 264.7 | 264.7 | 264.7 | 264.7 | 264.9 | 265.3 | 264.7 | 264.7 |
| | Sensitivity (%CCP/℃) | 0.785 | 0.784 | 0.783 | 0.784 | 0.785 | 0.783 | 0.783 | 0.784 | 0.784 |
| | Penalty for 2.7 °C | 2.1% | 2.1% | 2.1% | 2.1% | 2.1% | 2.1% | 2.1% | 2.1% | 2.1% |
| $DP_{HH}$ | Avg.(kPa) | 1222.0 | 1224.7 | 1232.4 | 1229.9 | 1244.8 | 1221.3 | 1223.4 | 1218.9 | 1214.1 |
| | Sensitivity (%CCP/kPa) | 0.0322 | 0.0322 | 0.0320 | 0.0320 | 0.0316 | 0.0323 | 0.0322 | 0.0324 | 0.0325 |
| | Penalty for 44 kPa | 1.4% | 1.4% | 1.4% | 1.4% | 1.4% | 1.4% | 1.4% | 1.4% | 1.4% |
| $P_{ROH}$ | Avg.(MPa) | 9.963 | 9.962 | 9.962 | 9.962 | 9.962 | 9.962 | 9.963 | 9.963 | 9.962 |
| Flow (kg/sec) | Total Flow | 8798 | 8772 | 8725 | 8747 | 8653 | 8808 | 8907 | 8802 | 8783 |
| | Difference* | 1 | **25**** | **72**** | **50**** | **144**** | **11**** | **110**** | **5** | **14**** |

* Difference of Heat balance flow vs. changed model flow
** Unacceptable error

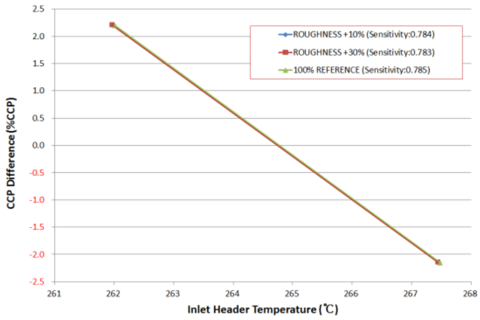


Fig. 1. %CCP sensitivities of $T_{RIH}$ for PT roughness 10% and 30% changes

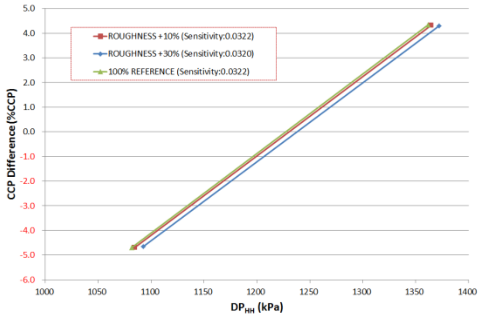


Fig. 2. %CCP sensitivities of $DP_{HH}$ for PT roughness 10% and 30% changes

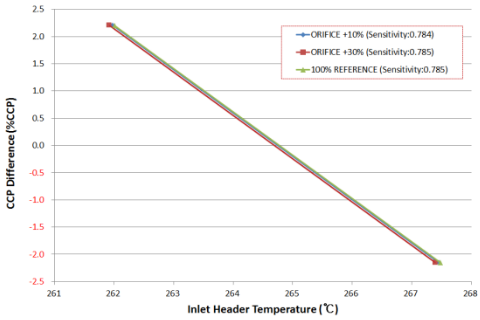


Fig. 3. %CCP sensitivities of $T_{RIH}$ for Orifice degradation factor 10% and 30% changes

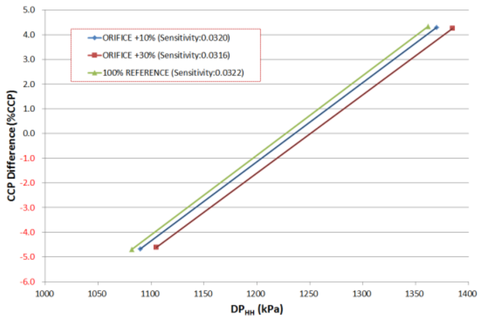


Fig. 4. %CCP sensitivities of $DP_{HH}$ for Orifice Degradation factor 10% and 30% changes

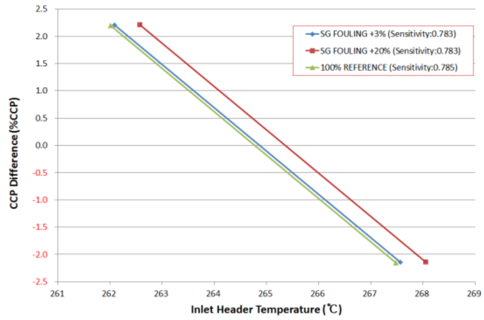


Fig. 5. %CCP sensitivities of $T_{RIH}$ for SG fouling factor 10% and 30% changes

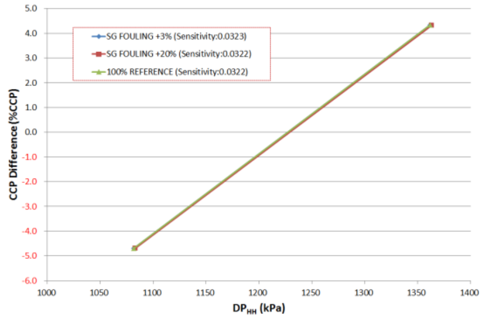


Fig. 6. %CCP sensitivities of $DP_{HH}$ for SG fouling factor 10% and 30% changes

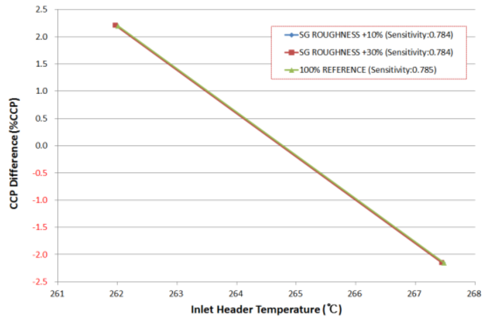


Fig. 7. %CCP sensitivities of $T_{RIH}$ for SG tube roughness 10% and 30% changes

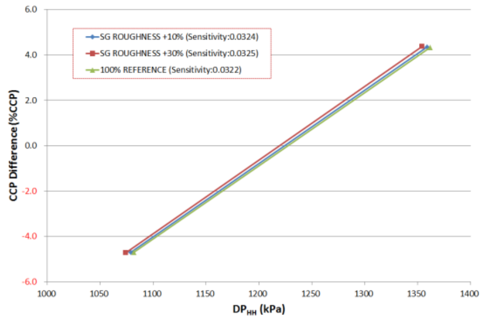


Fig. 8. %CCP sensitivities of $DP_{HH}$ for SG tube roughness 10% and 30% changes

## 3. Conclusions

The sensitivities by varying thermal-hydraulic parameters for CCP calculation were evaluated for Wolsong unit 2 reactor. Actually boundary condition data cannot be taken at 100% power condition at aged reactor condition. For confirming the uncertainties by variation PHTS model, sensitivity calculations were performed by varying of pressure roughness, orifice degradation factor and SG fouling factor, etc.

In conclusion, sensitivity calculation results were very similar and the linearity was constant. And the inherent uncertainty in the thermal-hydraulic model can be negligible by applying plant procedure of thermal-hydraulic boundary conditions penalty.

## REFERENCES

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[3] D. J. Wallace, NUCIRC-MOD2.003 User's Manual, 153-116190-UM-001, AECL, Jan.2006

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[5] D. J. Wallace, NUCIRC-MOD2.003R1(NUCIRC2.3.1) Program Abstract, 153-116190-SPA-001, AECL, Jan.2007