Verification of Compliance of Channel and Bundle Power Limits Considering Ageing

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1. Introduction

In the process of resolving GAI 95G03(Compliance with Bundle and Channel Power Limits) and 01G01(Fuel Management and Surveillance Software Upgrade), Canadian nuclear industry and its regulators upgrade their software like reactor physics code to a level of at least similar to the Industry Standard Toolset (IST). As results, power coefficients of reactivity have large uncertainty had become obvious.[1] If large allowances for uncertainties were needed, analysis must be carried out to ensure reactor safety.

To analyze this large uncertainty in power coefficient, uncertainty factors of power coefficient should be identified. Thus in this paper, sensitivity analysis on aging elements is performed by ascertaining envelope of channel power and bundle power. And Compliance with bundle power and channel power limits (GAI 95G03) considering aging effect is verified.

2. Method and Results about channel and bundle power considering aging effect.

2.1 Parameter related to aging effect

Parameters related to aging effect and operating parameters related to aging elements which can be used in SCAN-RELAP/CANDU are clarified in previous studies.[2] The aging elements are listed on Table 1.

Table 1: Aging elements related to operating parameter.

Component	Ageing element	Ageing Mechanism
Fuel channel	Roughness	Corrosion (magnetite precipitation)
	Loss Coefficient	Pressure Tube Creep & Sagging
	Hydraulic Diameter	Pressure Tube Creep & Sagging / Corrosion
	Flow Area	Pressure Tube Creep & Sagging
Pump	Pump Head	Degradation
	Pump Rated Flow	Degradation
Steam Generator	roughness	Corrosion (magnetite precipitation)
	hydraulic diameter	Corrosion (magnetite precipitation)
	S/G divider plates leakage area	Degradation
Inlet Feeder + End Fitting	roughness	Corrosion (magnetite precipitation)

According to previous studies, variation of operating parameter like reactor inlet header temperature, fuel channel flow can be caused by degradation. This contributes to the uncertainty of bundle and channel power.

2.2 GAI 95G03 and GSI AA 2 [3], [4]

The issue, "Compliance with Bundle and Channel Power Limits", is derived as a GAI 95G03 and GSI AA 2 from CNSC and IAEA respectively. To achieve closure of this item, additional analysis listed below should be performed.

A. Establishment of operating bundle and channel power envelops
B. Assessment and validation of errors in power measurements, power calculation methodologies and computer code

2.3 Method for ascertaining envelope of channel and bundle power considering Aging

A. Computational code: SCAN/RELAP-CANDU
   - SCAN: reactor physics code
B. Aging elements on Table 1 is considered conservatively.
C. Sensitivity analysis is performed on each aging elements. From this analysis, envelopes of fuel and bundle power are obtained.
D. Envelope and power limit are compared.[5]
   - Channel power limit: 7100kW
   - Bundle power limit: 906kW

2.4 The envelope of channel power

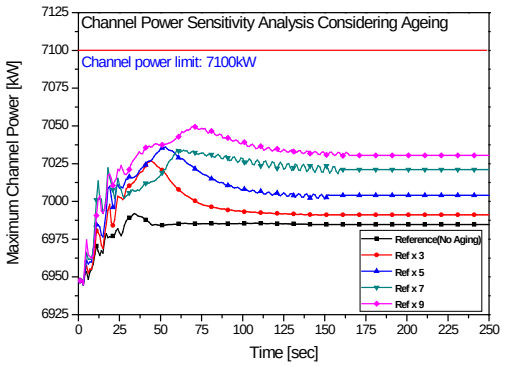

Fig 1: Channel Power Sensitivity Analysis Considering

Ageing #2 (fuel channel roughness)

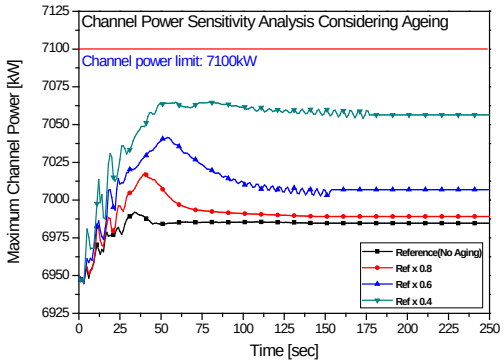

Fig 2: Channel Power Sensitivity Analysis Considering Ageing #2 (fuel channel hydraulic diameter)

Fig 1 and Fig 2 represent some results from sensitivity analysis of channel power. These figures show that safety margin is decreased considerably as degradation is more progressed. But these graphs denote that all envelopes didn't exceed channel power limit even though aging effect is over estimated.

2.4 The envelope of bundle power

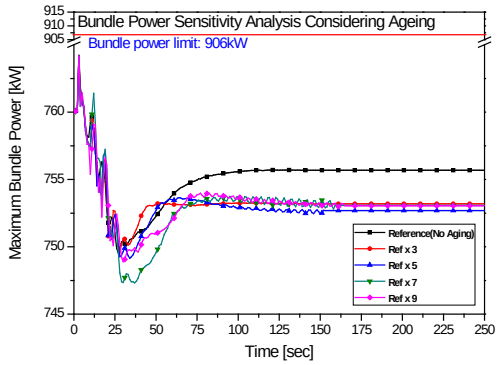

Fig 3: Bundle Power Sensitivity Analysis Considering Ageing #2 (fuel channel roughness)

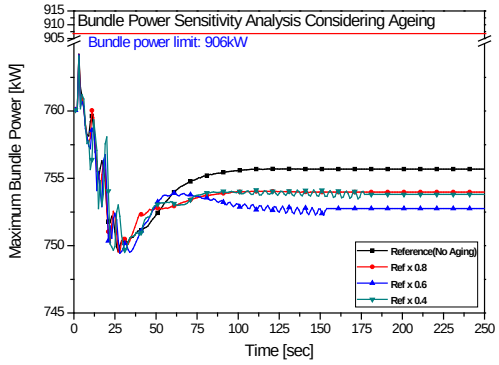

Fig 4: Bundle Power Sensitivity Analysis Considering Ageing #2 (fuel channel hydraulic diameter)

Fig 1 and Fig 2 represent some results from sensitivity analysis of bundle power. Contrary to Fig 1and 2, It seems to has no tendency between bundle power and aging effect. It is supposed that bundle power tend to decrease up to some extent and then increase over that range. All envelopes didn't exceed bundle power limit even though aging effect is over estimated anyhow.

3. Conclusions

In this study, envelopes of channel power and bundle power considering aging effect are obtained from sensitivity analysis. And then compliance of channel and bundle power is verified. These results would be used to analyze uncertainty of power coefficient and could contribute to achieve closure of GAI 95G03 and GSI AA2. To close the GAI 95G03 and GSI AA2, however, allowances and level of confidence should be determined and validation program of computer code is needed additionally.

REFERENCES

[1] Canadian Nuclear Safety Commission, "CNSC Technical Staff Perspective on CANDU Positive Void Reactivity", presentation slides, 3-4 July 2008.

[2] Y.W. Choi, M.W. Kim, "Development of Evaluation System of Safety Margin Effects for Degradation of CANDU Reactors Using RELAP-CANDU", ICAPP 2008, Jun 2008

[3] CNSC, "Canadian National Report for the Convention on Nuclear Safety", Second Review Meeting, October 2002.

[4] IAEA, "Generic Safety Issues for Nuclear Power Plants with Pressurized Heavy Water Reactors and Measures for their Resolution", IAEA-TECHOC-1554, June 2007.

[5] KEPCO, "FSAR, Wolsung unit 1"