Assessment Of Thermal-Hydraulic Aging Characteristics Of Wolsong-1 And Aging Predictions To Ensure Optimized Future Operation

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ABSTRACT

All industrial plants undergo changes with time and nuclear plants are no exception. Wolsong-1 started its' commercial operation in 1983. Through more than 20 years of operation the plant has experienced aging behavior in many aspects. Specifically, aging of Primary Heat Transport System (PHTS), can affect fuel cooling characteristics. This reduces the margin to Onset of Intermittent Dryout (OID) of the CANDU fuel, a criterion used to conservatively prevent the possibility of fuel failure under nominal and accident scenarios. The power level associated with OID defines the Critical Channel Powers (CCP). In order to mitigate margin degradation Wolsong-1 had cleaned the primary side of all steam generators in March of 2003, reducing reactor inlet header temperature. However, even with this action, degradation of margin is continuing. To track and assess the current conditions of the primary heat transport system components, data showing aging effects are acquired and steady-state thermal-hydraulic models are developed. The resulting analysis allows for optimum safe and economic reactor operation. The following issues are explored specifically with respect to Wolsong-1 nuclear reactor operation.

1. Pressure tube creep measurement, prediction, and model development
Radiation induced, increasing pressure tube diameters, specifically pressure tube diametral creep, cause more and more coolant to bypass the sub-channels of the fuel bundles, reducing margin to CCP. For Wolsong-1, pressure tubes were inspected in 1990, 1992, 1994, 2001 and 2004. Measurement in the nineties was done with the 'CIGAR' system and in the 21st century with the 'AFCIS' system. For each year's inspection, more than 12 channels are measured and some channels have been inspected in several years. The diameters of specific channels, repeatedly measured in more than three different years, allow an accurate diametral creep prediction. The initial manufacturing diameter and the aged, measured diameter of channels are used to assess the appropriate uncertainties associated with analysis model predictions.

2. Thermal-hydraulic model development
Plant operating data at around 80%FP are obtained to develop single phase thermal-hydraulic analysis models and data at 100%FP are gathered to confirm the ability of analysis models to simulate single and two phase operating conditions. Single phase operating data, acquired on June 8, 2004 (6577EFPD), and two phase operating data, acquired on June 16 (6585EFPD), are used for modeling of the Wolsong-1 PHTS. The Wolsong-1 thermal-hydraulic models reproduce the single-phase characteristics well. The two-phase operating conditions are also well predicted by the analysis models.

3. CCP and ROP trip set-point analysis
CCP is evaluated with constant PHTS header conditions and constant below-header flow-resistance conditions using the NUCIRC code. Over 800 cases of neutronic flux shapes are considered for CCP

evaluation. The Regional Overpower Protection (ROP) safety system ensures CCPs are not exceeded during nominal and accident scenarios. A corresponding ROP trip set point is evaluated with the ROVER code. The ROP analysis methodology of 98% trip probability and 90% confidence level and the worst 2 out of 2 trip logic is used.

4. ROP trip set-point aging trend prediction

The predictive reference models at 7500, 8500 and 9500 EFPD are prepared under the assumptions of increasing creep and constant model boundary conditions. These models consider flow redistribution due to pressure tube diametral creep. Associated ROP uncertainties are time dependent with pressure tube diametral creep related uncertainties yielding the largest contributors.

5. Wolsong-1's strategy to enhance the ROP margin

In order to regain ROP margin lost due to component aging, Wolsong-1 is considering a strategy of methodology accuracy improvements allowing higher ROP trip setpoints. Realistic modeling of the trip logic system and adoption of internationally accepted safety standards are also considered to regain ROP margin lost by plant aging.