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CANDU Core Health Monitoring Systems

by

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Abstract

Accurate information about the state of the reactor core is crucial to safety and production margins, especially as the reactor ages. Regional overpower protection (ROP) and spatial flux control in the relatively large CANDU core is provided by an extensive set of in-core flux detectors (ICFDs). The state of the reactor core as well as changes in the ICFDs themselves due to burn-up can be monitored by analysis of high resolution, high frequency data acquired from in-situ instrumentation during steady state operation and during transients such as reactor trips. AECL's CANDU Core Health Monitor is an integrated set of qualified software packages for data extraction, display and analysis of ICFD and reactivity / shut-down device data obtained during a reactor trip. CANDU station-qualified hardware tools for acquiring the necessary data at 16-bit resolution and up to 1 ms sampling intervals have also been developed and are available.

The software package enables a standard, qualified, and relatively quick performance assessment of (a) ICFDs, ion chambers (ICs) and associated electronics loops, and (b) a set of other reactor shut down system parameters such as negative reactivity insertion speed and depth. The Phase 1 software package includes an assessment of the impact of aging on performance of the safety system ICFDs and electronics loops, including a) a safety analysis of ICFD loop dynamics, b) algorithms to check ICFD loop performance against the safety analysis results, and c) calculation of optimized changes to the ICFD dynamic compensator parameters to maximize safety margins.

The benefits of the CANDU Core Health Monitor product include:

- Standardized, cost-effective and fully auditable analyses and responses to regulatory requirements for demonstration of safety system availability and effectiveness. This product will significantly reduce the trip analysis time and effort.
- Increased operating margin by reducing allowances that must be made for uncertainties in in-core flux detector dynamic responses and uncertainties in models of reactor flux distribution during transients

- Increased knowledge of the changes, due to burn-up and reactor core aging, in safety and control system ICFD and in-core device performance.
- Reduced OM&A costs due to standardized performance monitoring and resulting condition-based maintenance of ICFDs, reactivity devices, and shut-down devices.

The CANDU Core Health Monitor which uses in-situ instrumentation, is separate from but augmented by AECL's Travelling Flux Detector (TFD) Core-Monitoring service. The TFD is a miniature fission chamber and lead cable coiled and housed in a transportable shielded flask. The fission chamber is inserted into the "TFD" tube in CANDU SIR flux detector assemblies and, under computer control, scanned in and out of the core while recording the position and signal output of the fission chamber. The AECL TFD Core-Monitoring Service includes transportation of the TFD system to and from site, operation of the system at site and TFD data-analysis using qualified software packages.

The TFD data, acquired in various reactor operating modes, can be analyzed via qualified software packages to yield:

1. absolute calibration and burnup correction for vanadium in-core flux detectors
2. verification of flux-shape during commissioning and during extended operation to track effects of core aging as part of plant life management (PLIM) programs
3. assessment of changes in location of specific in-core components due to aging (e.g., channel sag, adjuster rod cable stretch and mechanical control absorber rod cable stretch) as part of PLIM programs
4. independent measurement of flux-tilts as a performance-measure of the effectiveness of the spatial control function in RRS
5. confirmation that the dynamic model of the flux during a transient (such as that obtained with the CERBERUS module in RFSP) is correct
6. verification of the dynamic response model used for in-core flux detectors (both safety and control)
7. verification of thermal power linearity

The benefits of TFD Core Monitoring Service include:

- Increased operating power by reducing allowances that must be made for (a) uncertainties in in-core flux detector responses and (b) uncertainties in models of reactor in-core flux and power distribution
- Direct support for a successful Plant Life Management (PLIM) program
- Increased knowledge of the changing state of an aging core and ability to answer regulatory questions on these changes