Linking CATHENA With Other Computer Codes Through A Remote Process

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ABSTRACT

CATHENA (Canadian Algorithm for THErmalhydraulic Network Analysis) is a computer code developed by Atomic Energy of Canada Limited (AECL). The code uses a transient, one-dimensional, two-fluid representation of two-phase flow in piping networks. CATHENA is used primarily for the analysis of postulated upset conditions in CANDU® reactors; however, the code has found a wider range of applications. In the past, the CATHENA thermalhydraulics code included other specialized codes, i.e. ELOCA and the Point LEPreau CONtrol system (LEPCON) as callable subroutine libraries. The combined program was compiled and linked as a separately named code. This code organizational process is not suitable for independent development, maintenance, validation and version tracking of separate computer codes.

The alternative solution to provide code development independence is to link CATHENA to other computer codes through a Parallel Virtual Machine (PVM) interface process. PVM is a public domain software package, developed by Oak Ridge National Laboratory and enables a heterogeneous collection of computers connected by a network to be used as a single large parallel machine. The PVM approach has been well accepted by the global computing community and has been used successfully for solving large-scale problems in science, industry, and business. Once development of the appropriate interface for linking independent codes through PVM is completed, future versions of component codes can be developed, distributed separately and coupled as needed by the user.

This paper describes the coupling of CATHENA to the ELOCA-IST and the TROLG2 codes through a PVM remote process as an illustration of possible code connections. ELOCA (Element Loss Of Cooling Analysis) is the Industry Standard Toolset (IST) code developed by AECL to simulate the thermo-mechanical response of CANDU fuel elements to transient thermalhydraulics boundary conditions. A separate ELOCA driver program starts, ends, controls, receives boundary conditions from CATHENA, calls ELOCA-IST subroutines for computation and sends feedback to CATHENA through PVM calls. The benefit of this dynamic link is that CATHENA's GENeralized Heat Transfer Package (GENHTP) is replaced with a specialized detailed model for CANDU fuel elements. The stand-alone plant conTROL Gentilly-2~~2~~ (TROLG2) program, developed jointly by AECL and Hydro-Québec, simulates the control system of the Gentilly-2 generating station operated by Hydro Québec. The dynamic link with a CATHENA plant idealization couples the thermalhydraulic reactor behavior to reactor control system behavior of the Gentilly-2 generating station plant during transient conditions.

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CATHENA can perform simulations of CANDU channels by dynamically linking with one or more ELOCA driver programs. Each link to an independent instance of the ELOCA driver program is associated with one fuel element having up to 20 axial nodes (current ELOCA-IST limit) and one circumferential segment. Figure 1 in the full paper shows graphically the data transfers involved in the connection between the CATHENA and ELOCA driver through the PVM interface. Variables transferred from CATHENA to ELOCA-IST at each time step are:

- number of axial segments,
- number of circumferential segments (currently one only),
- coolant pressure,
- coolant temperature,
- sheath-to-coolant heat transfer coefficient,
- thermal radiation heat flux, and
- power fraction.

Variables that are returned for each axial segment from ELOCA-IST are:

- fuel sheath temperature,
- fuel element outer diameter, and
- fuel length.

CATHENA linked with ELOCA through PVM allows independent development of separate codes and achieves direct coupling during execution ensuring convergence between the codes. This coupling also eliminates the preparation and conversion of data transfer necessary between the codes by an analyst. This coupling process saves analyst time while reducing the possibility of inadvertent errors and additionally provides a record of data transferred between the codes for verification.

CATHENA can also perform simulations of CANDU primary and secondary circuits by dynamically linking with the TROLG2 program. For the connection to the TROLG2 plant control code, 151 CATHENA variables are passed to TROLG2 through the PVM interface. Based on this information, control of valves, reactor power and other control data (89 variables) are passed back across the interface to CATHENA. This data transfer exchange is performed every CATHENA time step.

AECL is exploring the application of PVM for other analyses and for other reactor applications. Future efforts will explore the feasibility to link other codes (e.g., sub-channel code ASSERT-PV, reactor physics codes WIMS-IST DRAGON, or core analysis codes RFSP-IST DONJON) to CATHENA through the PVM remote process. Linking reactor physics or core analysis codes to CATHENA through PVM would be beneficial for development of the Super Critical Water cooled Reactor (SCWR), since water properties change significantly along the channel and during a transient event.