Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

Development of CANDU 6 Primary Heat Transport System Modeling Program

Hyung-beom Seo, Sung-min Kim, Joong-woo Park, Kwang-su Kim, Dae-hack Ko, Bong-seob Han,
Korea Hydro Nuclear Power Co., Wolsong Nuclear Power Plant 1, Safety & Engineering Dept.,
260, Naa-ri, Yangnam-myeon, Kyeongju-si, Kyeongsangbuk-do, KOREA, hbsar@khnp.co.kr

1. Introduction

NUCIRC is a steady-state thermal-hydraulic code used for design and performance analyses of CANDU Heat Transport System. The code is used to build PHT model in Wolsong NPP and to calculate channel flow distribution. Wolsong NPP has to calculate channel flow distribution and quality of coolant at the ROH header after every outage by OPP (Operating Policy & Principal). PHT modeling work is time consuming which need a lot of operation experience and specialty. It is very difficult to build PHT model as plant operator in two weeks which is obligate for plant operation after every outage. That is why Wolsong NPP develop NUMODEL (NUcirc MODELing) with many-years experience and a know-how of using NUCIRC code. NUMODEL is computer program which is used to create PHT model based on utilizing NUCIRC code.

2. CANDU6 Primary Heat Transport System Modeling

2.1 Primary Heat Transport System

A simplified composite flow diagram of CANDU 6 heat transport system is shown in Figure 1. There are two figure-of-eight loops making up the PHT; each loop consists of two core passes. Each core pass consists of one HT pump, one reactor inlet header (RIH), one reactor outlet header (ROH), one steam generator and 95-channel core pass. The configuration of each pass is as follows:

Loop	Core pass	Components
1	pass 2-3	P1-RIH2-ROH3-B2
1	pass 4-1	P2-RIH4-ROH1-B1
2	pass 6-7	P3-RIH6-ROH7-B4
2	pass 8-5	P4-RIH8-ROH5-B3

Both loops are indirectly inter-connected via the Purification and Pressure and Inventory Control (PIC) systems. The purification system interfaces with the pump discharge and pump suction line of HT pumps P1 and P3 located as shown in Figure 1. The PIC system interfaces with outlet headers ROH3, ROH7 via the common pressurizer piping located as shown in Figure 1. There is a header interconnect balance line between the outlet headers of a common loop (e.g., ROH1 to ROH3, ROH5 to ROH7) which is designed to increase the stability of the transport system by equalizing the pressure difference between outlet headers. The core consists of 380 channels.

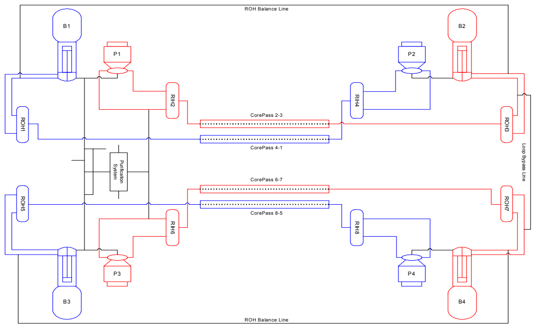

Figure 1. CANDU 6 Primary Heat Transport System

2.2 Modeling Procedure by using NUCIRC Code

NUCIRC code is composite of many modules, so called ITYPE, for modeling many ITYPE calculated result should be used and be integrated for next step calculation. Modeling is a work to calculate pressure, temperature, flow distribution of coolant and system component's roughness and performance etc. The 5 ITYPE are used to build PHT model in Wolsong NPP among many of ITYPE calculation in NUCIRC code. Each five ITYPE analysis boundary is as follow. ITYPE2 is for below header model from RIH header to ROH header includes 380 core channels. ITYPE8 is for purification system flow calculation. ITYPE7 is for steam generator from ROH header to RIH header included pump and stream generator. ITYPE9 is for pressurizer common loop bypass flow calculation. And ITYPE6 is for full circuit model of figure-of-eight.

2.2.1 Single Phase Modeling (at 80%FP or 75%FP level of reactor power for the single phase state of coolant)

Acquisition of site operation data → ITYPE2: Calculating total heat balance flow of whole core based on 380 inlet/outlet channel temperature and core power distribution obtained from RFSP(Reactor Fuelling Simulation Program) → ITYPE8: Purification flow circulation → Determination of each core pass Best Estimate flow → ITYPE2 Tuning → ITYPE6/7 Tuning(→ ITYPE8) → (ITYPE2 Tuning → ITYPE7 Tuning → ITYPE6) : Complete PHT modeling process when the tuning factors are converged within the limits. is done

2.2.2 Two Phase Modeling

Apply the site operation data of 100%FP to the PHT model which is created in single phase → ITYPE8 →

ITYPE6 → ITYPE2: Apply Header gradient model and component's roughness to ITYPE2 for calculating channel flow distribution and the quality of coolant.

2.3 Difficulty of manual PHT modeling

Each ITYPE of NUCIRC code is running separately. As shown in 2.2.1, ITYPE's results have to use for next step ITYPE running. For the iterative ITYPE running, process of result acquisition of previous step ITYPE running and apply this to the next step of ITYPE running is repeated until the entire system component's tuning factor reach within coverage limit. Modeling is time consuming, frangible for human error, asking high-skilled and many years experienced person for the job done. In spite of that, NUCIRC manual isn't appropriate for use of plant operators. To reduce a plant's difficulty of modeling, NUMODEL was developed.

3. Main contents of "NUMODEL"

3.1 Development and Using configuration

-. Server: Windows 2003 Server, MS SQL 2000
-. DB Access Interface: ADO (ActiveX Data Object)
-. Language: Visual Basic 6.0, Transact-SQL
-. Client Operation System: Higher than Windows 95
-. Using thermal-hydraulic codes
  .NUCIRC: NUCIRC-MOD2002R1PC.EXE
  .NUPREP: NUPREP-MOD2002R2PC.EXE

3.2 Development of built-in semi-auto tuning process with using and integrating previous step ITYPE result

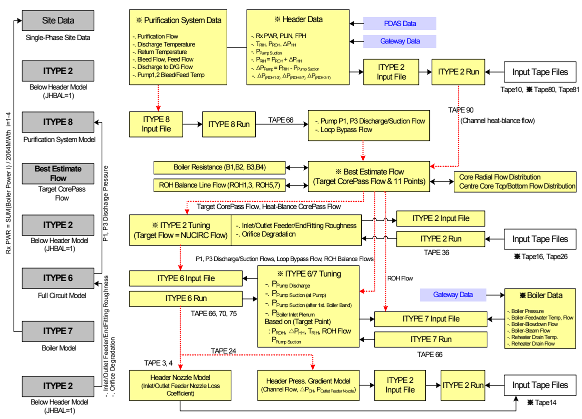

Figure 2. The scheme of semi-auto tuning process

3.3 Logic of the Best Estimate Flow Determination

-. ROH Balance Line Flow : Assumed ROH(1-3) Line, KLoop1 = ROH(5-7) Line KLoop2
-. QLp1(ROH Balance Line) = SQRT(ΔP(ROH1-3)/K)
-. QLp2(ROH Balance Line) = SQRT(ΔP(ROH5-7)/K)
-. K: User Input(User defined based on experience)

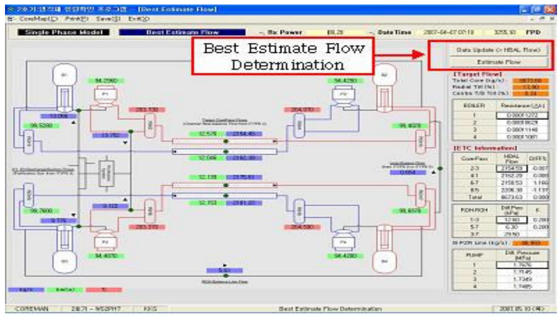

Figure 3. Determination of the Best Estimate flow

3.4 Logic of the auto result acquisition and tuning factor value suggesting loop (Iteration Tuning)

ITYPE2 Tuning factor are Inlet/Outlet Feeder and End Fitting Roughness, Orifice Degradation (Orifice Correction Factor), MAPPRINT Utility is included in this logic.

ITYPE7/6 Tuning: Program suggests tuning value for next iteration. Tuning value are Pump Head, Roughness (Hot Leg/ Preheater/ Cold Leg). New ROH/RIH Boundary Condition Value are Outlet Header Exit Press, Inlet Header Entrance Press, PHT Pump Head, NEXT Pump Suction Target. New Pressurizer Piping Pressure.

3.5 Data base of Modeling history and PHT ageing trend management

4. Conclusion

4.1 Result Verification of Manual and NUMODEL using Modeling

Verify modeling result by comparing two modeling of manual and using NUMODEL. The core flows of two methods are both similar and within coverage criteria. Modeling using NUMODEL is much easier than the other method with almost same result. Wolsong NPP can save time and man-power by using NUMOEL. Wolsong NPP developed NUMOEL (PHT modeling program) for the first time among CANDU 6 station in the world.

4.2 Improvement of using "NUMODEL"

–	Manual Modeling	Using " NUMODEL"
Tuning	By using Excel Sheet	Auto tuning by " One-Click"
Time for modeling	More than two weeks with over-time work	Below two days
Human Error		Minimize
Modeling Result	Similar	

Table 1. Improvement of using NUMODL

REFERENCES

[1] Canada AECL, by F.L. Huang "NUCIRC User's Manual" TTR-421-Revision 4