Development of CANDU-6 Moderator System Safety Analysis Model Using the CATHENA Code

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1. Introduction

The moderator system of CANDU-6 reactor (PHWR type) is a safety related system and the primary safety functions are to maintain the moderator as a heat sink for the reactor core by providing heat removal and, for a certain accident such as LOCA with loss of ECCS, to provide a final heat sink by removing large quantities of heat from the fuel channels. Therefore, failure of moderator system is one of design base accident (DBA) in CANDU-6 plant. Thermalhydraulic safety analysis for the moderator system failure has been done using the MODSTBOIL code until recent safety analysis for both domestic and Canadian nuclear power plants. However, this MODSTBOIL code has a few important deficiencies that is, does not model the head tank and moderator system piping and relief ducts are modelled using the one node, and in Canada this code does not meet the CSA N286.7(QA of Analytical, Scientific and Design Computer Programs for NPP) requirements. Therefore, for the advanced and sophisticated analysis for the moderator system failure, we developed new safety analysis model using the CATHENA code which is the state-of-the-art code in the field of CANDU-6 thermalhydraulic analysis and meets the CSA N286.7.

2. Introduction to Moderator System

CANDU-6 plant moderator system is divided into main moderator system and cover gas system.

2.1 Main Moderator System

Main moderator system provides the forced circulation of moderator and heat removal from the moderator downstream of calandria outlet nozzle and this system is composed of moderator circulation pump(2 EA, 100% each), heat exchanger(2 EA, 50% each) and various piping system as shown in Figure 1.

2.2 Cover Gas System

The safety functions of cover gas system are to provide a pressure on the moderator liquid to ensure adequate subcooling of the moderator and to provide the overprotection for the pressurization transients.

Another safety function is to remove the deuterium produced by radiolysis of the moderator and to recombine it with oxygen. This function is evaluated other chemical analysis code of DEBUT.

Helium is used as the cover gas because it is inert and reduces corrosion in the system as compared to air.

Cover gas system is composed of 4 relief ducts, rupture disks for each relief duct for protection of over pressurization of calandria, 2 compressors, deuterium recombiner unit, head tank, helium supply tank, cover gas bleed valves as shown in Figure 2.

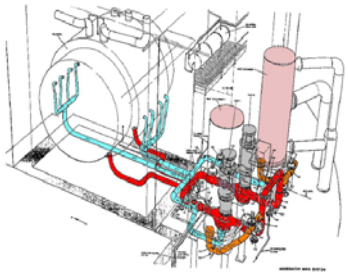

Figure 1. Composition of the Main Moderator System

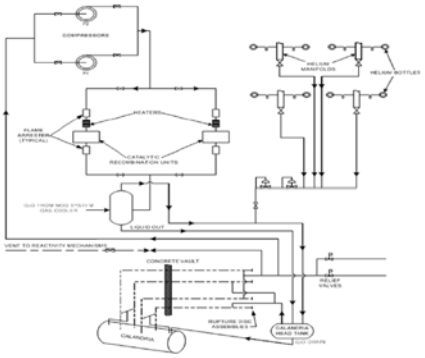

Figure 2. Composition of the Cover Gas System

3. Methodology for CATHENA Model

The modeling methodology applied to CATHENA moderator system is shown in Table 1 and Table 2 for main moderator system and cover gas system, respectively

Table 1. Modeling Methodology for Main Moderator System

Component	Model Method
Calandria	Generalized TANK Model - Upper/Lower Region of Calandria - Moderator Level Tracking
Head Tank	Generalized TANK Model - Upper Region : Cover gas - Lower Region : Moderator

Circulation Pump	User 1-P model Pump Characteristic Curve
Heat Exchanger	Simplified Moderator Temperature Control(MTC)) Logic, Heat Input B.C
Piping	Component Model following Design

Table 2. Modeling Methodology for Cover Gas System

Component	Model Method
Cover Gas Compressor	Saturated D2O Steam Reservoir B.C with 21kpa(g) Flow B.C with 4.7 l/sec
Helium Supply Tank	Reservoir B.C with 21kpa(g)
Bleed Valve	Valve Model with opening at 28kPa(g) and closing at 24kPa(g) - Capacity : 556 l/sec
Rupture Disk (4)	Discharge Model - Capacity : 3020 kg/sec
Piping	Component Model following Design

And the methodology applied to the transient analysis for three kinds of events- Loss of Moderator Circulation (LOMC), Loss of Service Water to Heat Exchangers (LOSW) and Loss of Moderator Inventory (DRAIN)- are shown in Table 3.

Table 3. Modeling Methodology for the Transients

Event	Model Method
LOMC	RPM of Pump decreased to 0 at 15sec after event start
LOSW	Heat Input B.C changes to 0 from -50MW per each heat exchanger
DRAIN	Drain Valve Model at bottom of Calandria

Using the above methodology we have developed the CATHENA model for the moderator system failures safety analysis which has the following 2 nodalizations (Figure 3 and 4) of main moderator system and cover gas system, respectively. And the Table 4 shows the comparison results between the design values of Wolsong-1 moderator system and the steady state initial conditions of the developed CATHENA model

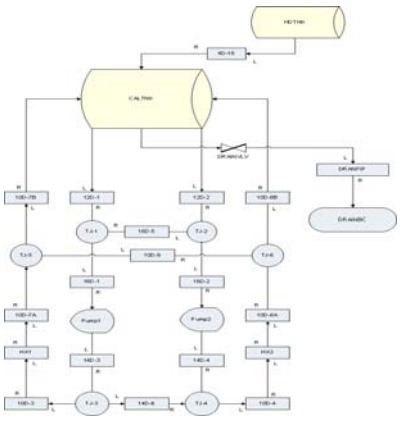

Figure 3. CATHENA Nodalization of Main Moderator System

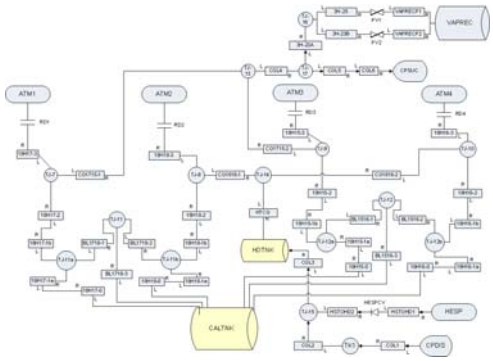

Figure 4. CATHENA Nodalization of Cover Gas System

Table 4. Comparison between Design Value of Wolsong-1 Moderator System and Steady State Condition of CATHENA Model

Parameter	Design Value	Analysis Value
Moderator		
- Level	7900 mm	7900 mm
-Outlet Temperature	69 ℃	69/73 ℃
Moderator Heat Load	96.7 MW(th) @ 100% FP	100 MW(th) @ 100% FP
Moderator Flow	940 *l*/s	940 *l*/s
HX Exit Temperature	46 ℃	46 ℃
Cover Gas		
- Gas	He	Saturated D2O Steam with condensation turned off
- Operating Pressure	21kPa(g)	24 kPa(g)
- Addition Rate	2.83 *l*/s	2.5 *l*/s

4. Conclusion and Forward Work

In order to take place of MODSTBOIL code which has been used for safety analysis of CANDU-6 moderator system failure, a brand new model has been developed using the CATHENA code and the steady states condition of the model shows a good coincidence with the design value of the plant. The developed CATHENA model would be verified against the plant operation data and the CATHENA model would be coupled with reactor physics code (RFSP/CERBRRS) model which is also under developing, to calculate the reactor core behavior for the moderator system failure more accurately.

5. Acknowledgment

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REFERENCES

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