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Comparison Study on Thermal-Hydraulic Analysis Depending on Liquid Relief Valve Response for an Station Blackout in CANDU-6

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1. Introduction

The purpose of this analysis is to compare the results of thermal-hydraulic analysis depending on liquid relief valve response during a station black out (SBO) events in CANDU-6. The primary heat transport system (PHTS) behavior following the postulated SBO is analyzed using CATHENA code.

2. Description of CANDU-6

CANDU-6 core is subdivided into two symmetrically located figures in two loops. Each loop consists of two core passes with 95 channels each. The core has 380 fuel channels arranged in 22 rows and 22 columns. In the CATHENA model, the channel groupings are based on channel power and elevation. In each core pass, channel groups 1 to 4 contain high power channels located in the inner region of the core and groups 5 to 7 contain lower power channels located in the periphery of the core. The CATHENA model includes a detailed representation of the PHTS and the pressure and inventory control network [1].

Steam Generators (SGs) provide heat sinks containing enough inventories to remove the decay heat from the core. Sixteen Main Steam Safety Valves (MSSVs) are available to relieve the SG secondary side pressure and they proportionally open from 4.9MPa(a) to 5.10MPa(a) by applying with -4% uncertainty.

For the simulation of pressurization event, the Liquid Relief Valve (LRV) and Degasser Condenser Relief Valve (DCRV) are modeled as described in Figure 1. The PHTS pressure is mainly controlled by LRVs and the Degasser Condenser Tank (DCT). The LRVs are air-operated with backup instrument air and are designed to fail open. During the Class Ⅵ power loss sequence, the LRVs fail open and the steam and water flow into the DCT. The pressure of DCT increases as the coolant discharges into the DCT through LRVs. The DCT has spring-loaded safety valves, DCRVs which are opened into the reactor building when the DCT pressure exceeds 10.16 MPa(a). DCRVs have a opening size of 2"x3", which expands proportional with the pressure with a certified water capacity of 32.3 kg/s, but 25 kg/s of discharged water was assumed in CATHENA to be conservative [2].

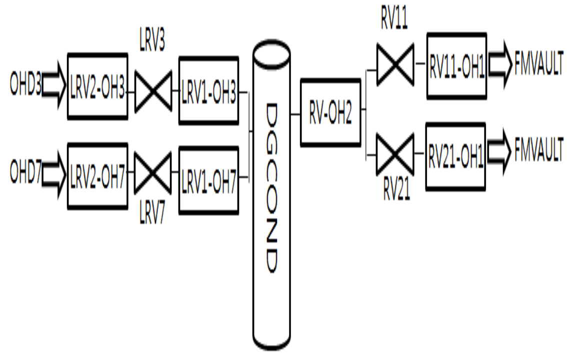

Fig. 1. CATHENA Model for DCRV

3. Analysis Results

3.1 Opening at setpoint of LRV

The important event sequence is described in Table 1. Because the PHTS pumps are not available due to the loss of power, the fuel heats up. The decay heat is transferred to the coolant and temperature gradient develops into the steam generator U-tube region, which promotes natural circulation of PHTS coolant.

The decay heat is transferred to the secondary side of the steam generators, which results a decrease in the PHTS pressure. At this point, the secondary side of the steam generators has sufficient heat sink capacity to absorb the decay heat. The heat transferred from the PHTS to the steam generators causes the water in the steam generator secondary side to boil off. As a result, the pressure in the secondary side of the steam generators increases and causes the MSSVs to open, discharging steam to the environment outside the reactor building. The water level in the steam generators decreases as boiling proceeds and the feedwater is not supplied to SG. When the water in the steam generators is depleted at approximately 5,600 seconds, the steam generators dry out and is not available a heat sink that can remove heat from the PHTS.

Table 1. Event Sequence for SBO

Event	Time (sec)
Reactor Trip, PHTS pumps stop, Feedwater flow to SGs stop	0
MSSV open	3
SG empty	4,800
DCRV liquid/steam discharge	6,500
Peak PHTS pressure	7,800

As shown in Figure 2, the PHTS pressure increases to cause opening of the LRVs at 5,600 seconds. After 6,500 seconds, the LRVs remain open continuously. At this time, the pressure in the degasser condenser is high enough to cause the DCRVs (3332-RV11 and 3332-RV21) to open. The DCRVs flow increases to maximum of 25 kg/s at each valve at around 6,500 seconds. At 7,500 seconds, DCRV discharges mostly steam and the PHTS pressure increases to maximum of 13.5MPa(a) around 7,800 seconds. Then the PHTS pressure starts to decrease.

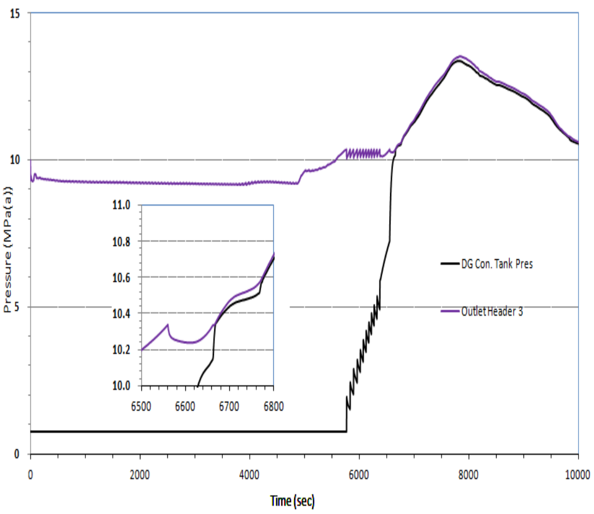

Fig. 2. PHT and DCT pressures of CATHENA(LRV opening at setpoint)

3.2 Fail Open of LRV

As LRVs open at 0 second, the pressure of degasser tank increases to the pressure of reactor outlet header within 24 seconds as shown in Figure 3. Pressure of primary side rises as the inventory of SG secondry side dries and DCRVs start to open at around 6,650 seconds, as the pressure of DCT approaches the setpoint. Mixture of liquid and steam is released through DCRV, and the pressure of the primary side rises up to 13.3MPa(a) at approximately 7,800 seconds where liquid release is at its maximum. Afterwards, the pressure of the primary side starts to decrease.

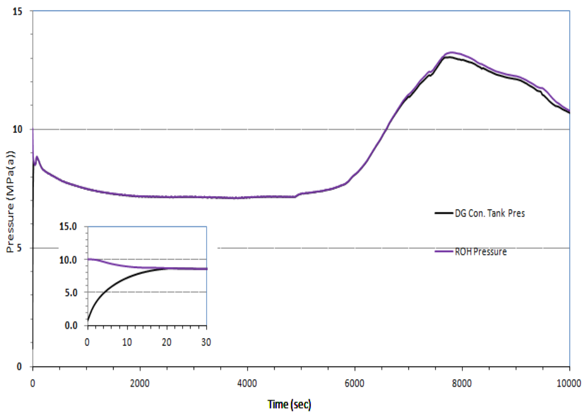

Fig. 3. PHT and DCT pressures of CATHENA(LRV fail open)

4. Conclusion

In the paper, analysis was performed to evaluate the effect on coolant system where LRVs are assumed to be opened or opened according to normal open characteristics in the condition of SBO. The result showed that the primary pressure boundry is extended from LRV to DCT and the effects on primary system behavior were neglectable.

REFERENCE

[1] B.N. Hanna, "CATHENA A Thermal-hydraulic Code for CANDU Analysis," Nuclear Engineering and Design 180 pp. 113-131 (1983).
[2] R, Oris, "Sustained Loss of All Heat Sinks Events in CANDU", CANDU Energy Presentation Material, Mar 2012.