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Best Estimate Approach for the Simulation of Void Reactivity of CANDU Type Reactor using the MARS Code

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1. Introduction

The application of the methodology of the best estimate(BE) calculation has been done to estimate the effect of void induced reactivity for a large break loss of coolant(LBLOCA) in CANDU plants. Analysis is performed using MARS (Multi-dimensional Analysis of Reactor Safety) code to check the role of void generation on power transient for LBLOCA (Large Break Loss of Coolant Accident) with break size equal to 35% of inlet header flow area. As generic methodology adopted in CANDU design's thermo-hydraulic codes use external reactor power source, reactivity induced power must be modeled to simulate LBLOCA using the MARS code. In this study part of reactor core was modeled using Point Kinetic Equation(PKE) model of MARS which comprises of reactivity feedbacks of coolant temperature, fuel temperature and coolant void, then the effect of coolant void reactivity(CVR) are evaluated. As a result, PKE model simulates power transient well and the void effect of coolant was important role in the decrease on coolant event and further works are needed to quantify the effect of each reactivity feedback.

2. Methods and Results

In this section MARS modeling and analytic assumptions are described.

2.1 MARS Idealization

The primary circuit, secondary circuit and ECC system are simulated using MARS.[1] The total number of control volumes used in the model is 547 and total number junctions used are 580. Each channel is modeled as a CANDU Channel component (CANCHAN) of twelve volumes. To model whole reactor core, 4 loop which represents 95 channels of similar power, location, power profile are grouped. Among the 4 loops, broken loop was divided to 7 sub-groups to represent critical transient path.

The break is modeled as a trip valve and connects inlet header (IHD8) to containment atmosphere which is modeled as time dependent volume. The valve area signifies the break area. Henry-Fauske critical flow model is used. Fig. 1 shows the primary system nodalisations and table I presents the number of channels for each along with the power.

Table I : The number of channels and power of each loop

Loop No	MARS Component Code	Number of Channels	Power (MWth)
1	100	95	5.561
2	200	95	5.552
3	300	95	5.552
4-1	25	12	6.452
4-2	35	12	6.522
4-3	45	11	6.619
4-4	55	14	6.397
4-5	65	16	4.406
4-6	75	15	4.945
4-7	85	15	4.372

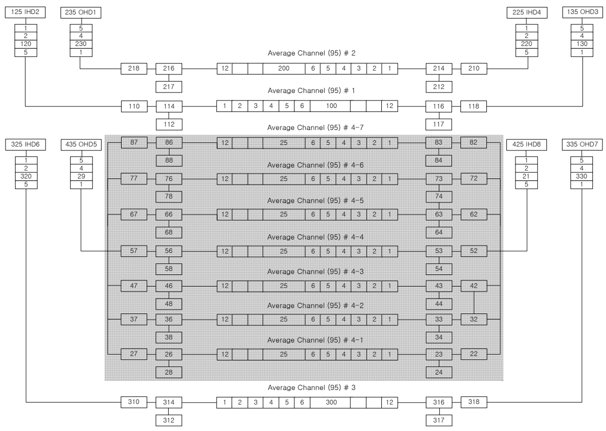

Fig. 1. Primary System Nodalisation

2.2 Part PKE Model

The power in loop3 was re-modeled using reactor kinetics models in MARS code.[2, 3] To evaluate the effect of void on system power, feedback table options of MARS(300019C1~C9, 30002011~2999) was used and the used feedback data was shown in table 2~4. [5]

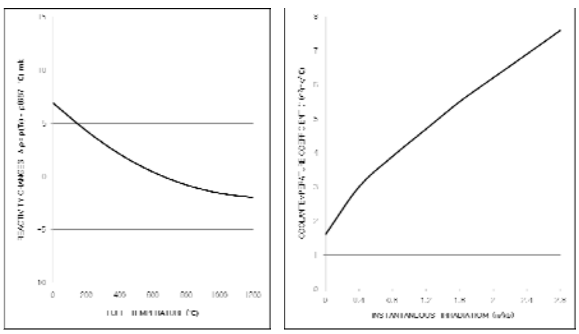

Fig. 2. Fuel and Coolant Temperature Coefficient of Wolsong-1

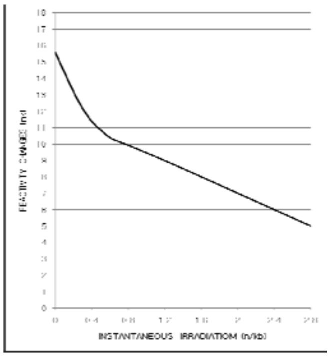

Fig. 3. Full Power CVR of Wolsong-1

Using reactivity coefficients in figure 2~3, with design scram reactivity data, we can obtain PKE response power that is nearly equivalent time dependent behavior like the external power source which comes from RFSP code in Wolsong-1 design analysis.(Fig. 4)

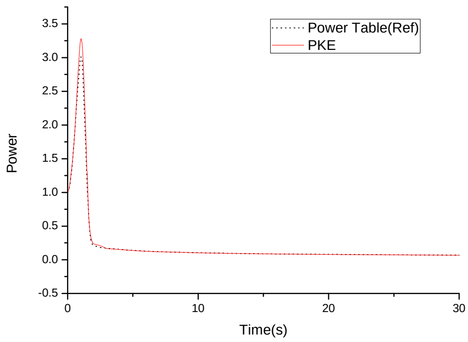

Fig. 4. Comparison of PKE power transient with reference power source

2.3 LBLOCA Transient

For our analysis, the steady state was achieved after a code run of 500 sec. During the initial 2~3 seconds after large LOCA event, increasing power makes reactivity build up that makes power peak and maximized system unstability like fuel melt or clad failure. Reactor trip based on PKE was modeled and the power trip models in non-PKE loops follows the reactor trip. Figure 5 shows the amount of void developed in core channels.

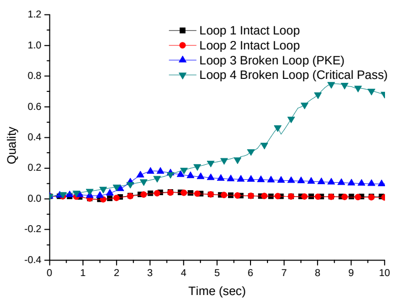

Fig. 5. Inlet Header Quality during LOCA Event

Figure 6 shows the effect of CVR during the LOCA event. Large void coefficient makes fast reactor trip and large peak power. As in figure 3~4, the overall result of the net CVR of the standard CANDU is positive, but decreases with burnup. In equilibrium core the CVR ≈+10 mk. But it is not physically possible to lose all the coolant instantaneously, therefore there cannot be an instantaneous insertion of +10 mk. In addition, reactivity insertion in a LBLOCA can be reduced by the number of loops. Therefore, the reactivity insertion in a LBLOCA may be of the order of 2~3 mk in the first second after the break. But, the rate of change was more faster than other reactivity feedback, the amount of reactivity insertion is more greater than that of coolant temperature or fuel temperature.

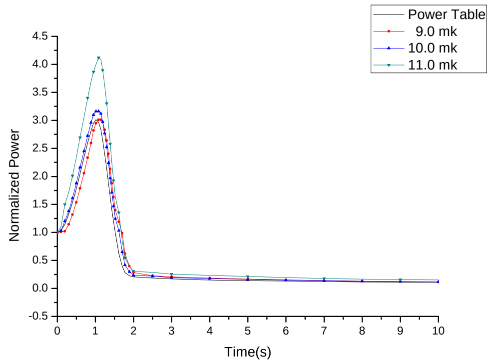

Fig. 6. Power Transient during the LBLOCA .vs. coolant void coefficient

3. Conclusions

LBLOCA simulation for CANDU type reactor using part PKE model was developed for the evaluation of coolant void reactivity. As a result, proposed simulation provides useful information about the role of void during the coolant reducing transient, and shows acceptable power transient simulations and importance of CVR. As coolant voiding is not uniform in large LOCA event, to evaluate the design based role of coolant void on power transient, we need more neutron kinetic data and computer code development to accommodate multiple core concept.

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