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Analysis of Steam Generator Injection Strategy During Severe Accident in PHWR

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1. Introduction

Injection into Steam Generators(SGs) is chosen one of severe accident management strategies in WOG SAMG[1] and CEOG SAMG[2]. If the feeder water is supplied to the SGs before the reactor vessel failure, then the natural circulation between the reactor core and SGs is established for high pressure accidents in pressurized water reactor (PWR). This natural circulation transfers the heat generated in the core to the SGs and may prevent the reactor vessel failure. SAMG for Wolsong Plant also adopted the injection into SGs as one of severe accident management strategies. This paper evaluates the effectiveness of this strategy. ISAAC[3] code is used to evaluate SG injection strategy for various accident sequences.

2. Accident Sequence Analysis

2.1 Plant modeling

ISAAC code[3] is used to simulate severe accidents in Wolsong Plant which is a CANDU6. Primary heat transport system (PHTS) consists of two loops and each loop has 190 fuel channels and 2 steam generators. 190 fuel channels are divided into 6 groups vertically and 12 nodes horizontally. Moderator system consists of a calandria vessel which is filled with heavy water, two pumps and two heat exchangers. End shield cooling system consists of two end shields, pumps, heat exchangers and a calandria vault which is filled with light water. Reactor building is divided into two fuel exchange rooms, a moderator room, a basement, an upper dome, a dousing tank, a degasser condenser tank, steam generator rooms, and an access room.

2.2 Accident simulation

During the normal operation, two loops are connected. If there exists pressure difference between two loops, then two loops will be separated by closing the isolation valve which connects two loops. If LOCA signal is generated, the loop isolation valve closes and the unbroken loop dose not lose its water inventory. This water inventory is maintained while the SGs have the water inventory in the secondary side. To investigate the effect of SG injection, three kinds of accidents are analyzed. These accidents are a Large break LOCA, a small break LOCA and a total loss of feedwater accident. The PHTS pressure is low, medium and high, respectively

3. Results

3.1 Large break LOCA

Guillotine break at the reactor outlet header 1 (ROH 1) is selected as a large break LOCA. Engineering safety features are not actuated to accelerate the accident progression. The feedwater is also assumed not to be supplied to the SGs. As the break occurs, the pressure difference between the loop 1(broken loop) and 2 (unbroken loop) generates a loop isolation signal and the two loops are isolated. In the broken loop, the coolant flows out the loop through the break, the fuels are uncovered at 20 second and the core water becomes empty at 680 second. The decay heat is transferred to the moderator in the calandria. For the unbroken loop, the natural circulation delivers the decay heat generated in the core to the SGs and SGs become dry at 3,361 second. After the dryout of SGs, the decay heat in the unbroken loop is also transferred to the moderator. Rupture disc in the calandria fails at 5,620 second due to overpressure and the saturated moderator evaporates and the fuel channels become uncovered. At 6,927 second, fuel channels in the broken loop fail and fuels start to relocate to the bottom of the calandria. Fuels in the unbroken loop start to relocate to the bottom of the calandria at 10,578 second. The calandria fails at 132,100 second and the reactor building fails at 132,203 second. To see the effect of the SG injection, the auxiliary feedwater is assumed to be established at 9,000 second, which is about 55 minutes after the use of the severe accident management guidance (SAMG). The transition from the EOP to the SAMG is done just after the top fuel channels become uncovered. As the auxiliary feedwater is supplied to the SGs in the unbroken loop, SGs recover their functions and remove the decay heat generated in the unbroken loop. The decay heat of corium from the broken loop, i.e. half of the total decay heat, is not enough to fail the calandria and the reactor building up to 72 hours from the accident initiation. When the auxiliary feedwater recovered at 9300 second, the injection into SGs is useless. For this case, the fuel channels in the unbroken loop also fails at 10,673 second relocate to the bottom of the calandria.

This results in the calandria failure at 132,954 second and the failure of reactor building at 133,050 second.

3.2 Small break LOCA

The break area of 0.01325 m^2 at the reactor inlet header 1 (RIH 1) is selected as a small break LOCA. Engineering safety features are not actuated to accelerate the accident progression. The feedwater is also assumed not to be supplied to the SGs. Two loops are isolated at 103 second due to pressure difference between loops. In the broken loop, the fuels are uncovered at 1,647 second and the core water becomes empty at 5,590 second. SGs become dry at 2,758 second and the core has uncovered at 8,403 second and has become empty at 9,658 second in the unbroken loop. At 9,739 second, the rupture disc in the calandria fails due to overpressure and the fuel channels become uncovered. At 11,316 second, fuel channels in the broken loop fail and fuels start to relocate to the bottom of the calandria. Fuels in the unbroken loop start to relocate to the bottom of the calandria at 11,741 second. The calandria fails at 137,424 second and the reactor building fails at 137,620 second. To see the effect of the SG injection, the auxiliary feedwater is assumed to be established at 10,000 second, which is about 4 minutes after the entrance of the SAMG. For this case, the injection time is too late to prevent the core melt. Fuels in the unbroken loop start to relocate to the bottom of the calandria at 12,226 second.

3.3 Total loss of feedwater accident

All SGs become dry at 2,748 second. The rupture disc in the calandria fails at 5,477 second due to overpressure and the fuel channels become uncovered after that. At 6,692 second, fuel channels in the both loops fail and fuels start to relocate to the bottom of the calandria. To evaluate the effectiveness of SG injection strategy, it is assumed that the auxiliary feedwater is supplied to the all SGs at 7,100 second which is about 10 minutes after the entrance to the SAMG. But it is determined that SG injection is useless. Fuel channels are ruptured regardless of SG injection.

4. Conclusions

Injection into SGs is one of severe accident management strategies for Wolsong Plant. The effectiveness of this strategy is evaluated for various accident sequences using ISAAC code. Based on the ISAAC calculation, we may conclude that this strategy is very effective for a large LOCA. For a large LOCA, the severe accident progression is terminated by the injection into SGs. But this strategy is determined not to be effective to prevent or to delay core melt for a small LOCA and a total loss of feedwater accident. Fuel channels fails if the feedwater is supplied after the entrance to the SAMG. The feedwater should be supplied to the SGs before the entrance to the SAMG to prevent or to delay the failure of fuel channels.

REFERENCES

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