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Analysis of Reactor Building Flooding Level for CANDU Reactor

Lee Youngseung [a*], Shin Jungmin [a]
[a] *Central Research Institute, 70, 1312-gil, Yuseong-daero, Yuseong-gu, Daejeon*
[*] *Corresponding author: leeys8807@khnp.co.kr*

1. Introduction

The external cooling water injection paths for the mitigation of a severe accident are installed for coping with station blackout. The additional cooling water is necessary for removing continuous core heat, while flooding level in reactor building can rise. Increased water level can cause the equipment for dealing with severe accidents to be unavailable.

The purpose of this paper is to analyze maximum flooding water level when using external cooling water injection lines.

2. Methods and Results

In this section, large loss of coolant accident (LLOCA) was chosen and analyzed, because the scenario was conservative in view of flooding level in reactor building. The analyzed code for LLOCA used Integrated Severe Accident Analysis code for CANDU plants (ISAAC 5.01).

2.1 Design of CANDU Plant for LOCA

Emergency core cooling system (ECCS) in CANDU reactor has been designed for loss of coolant accident (LOCA). ECCS consists of high pressure (HP) ECCS, medium pressure (MP) ECCS and low pressure (LP) ECCS as shown in Fig1. HPECCS such as accumulators for pressurized water reactor (PWR) provides cooling water in pressurized ECCS tanks to primary heat transport system (PHTS). MPECCS supplies cooling water of dousing tank in reactor building to PHTS using the ECCS pumps. LPECCS recirculates cooling water in the sump of reactor building and the recirculation operation is used for the long term core cooling. LOCA signal actuates 55% of operating pressure and ECC tanks pressurize 40% of operating pressure. Accordingly, cooling water in ECC tanks can inject into PHTS if the decreases of PHTS pressure, which main steam safety valves (MSSVs) are open, are accomplished. If LOCA signal actuates, loop isolation occur for preventing all PHTS inventory from discharge. Total available mass of cooling water for LOCA is about seven hundred tons.

CANDU reactor has the passive spray system for decreasing reactor building pressure. The spray system consists of dousing tank and spray valves. If spray valves open, cooling water in dousing tank is discharged by gravity.

Cooling water such as spray water and core cooling water collected in the recirculation sump in reactor building basement.

Equipment related to safety shutdown is located about 2.6 m above basement floor [1]. Specially, most transmitters of reactor trip parameters are installed.

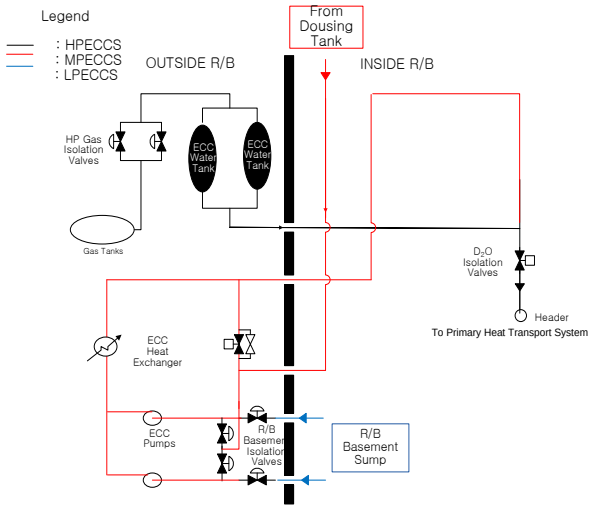

Fig.1. Composition of ECCS

2.2 Analysis of Flooding Level for Base Case

The selected scenario was LOCA and analyzed time was seven days, because the LOCA scenario was conservative in view of flooding level in reactor building. Additionally, it was assumed that the cooling water of dousing tank and ECCS tanks were discharged into reactor building, and that local air coolers (LACs) were operated but ECCS pumps were unavailable for progression of severe accident. Accordingly, the operation of LACs prevented the reactor building failure from overpressure during severe accident.

The analyzed results of LOCA base-case were shown in Table 1. Entry time of severe accident was about 9.7 hours because of ECC tank cooling water and cooling through steam generators.

Table1. Results of LOCA base-case analysis

Events	Time
Reactor Scram	0.9 s
LOCA signal received	3.5 s
Loop Isolation	23 s
MSSV open	33.5 s
ECCS tanks depleted	255 s
Dousing tank depleted	2,470 s
Severe accident entry	9.7 hr
Depletion of water in Calandria tank	22.4 hr
Maximum flooding level (m)	
2.5	

Calandria tank was intact during seven days. Also the maximum flooding level in reactor building was about 2.5 m above basement floor.

2.3 Analysis of Flooding Level under External Cooling Water Injection

CANDU reactors in Korea planned to install external cooling water injection lines for PHTS and Calandria vault. Accordingly, if considered those external water paths, flooding level in reactor building estimated to increase higher level than the LOCA base-case scenario.

The flow rate of the external cooling water line for PHTS assumed about 19 kg/s [2], and that of vault makeup assumed about 5 kg/s. Also, it assumed that external cooling water for PHTS injects into PHTS according to Calandria tank level and that vault makeup water is provided into Calandria vault according to decrease of Calandria vault level [3].

Though both external cooling water for PHTS and that for vault were available at four hours after severe accident entry time, Calandria tank makeup water only injected due to slow decrease of Calandria vault level.

As shown in Table2, maximum flooding level during seven days was about 2.62 m, total makeup mass was about 1,150 tons. Also, Fig 1 showed Calandria tank level, Calandria vault level and makeup source inventory, and Fig 2 provided the basement water level in reactor building and reactor building pressure.

Table2. Results of LOCA case plus external cooling water makeup

Events	Time
Reactor Scram	0.9 s
LOCA signal received	3.5 s
Loop Isolation	23 s
MSSV open	33.5 s
ECCS tanks depleted	255 s
Dousing tank depleted	2,470 s
Severe accident entry	9.7 hr
External cooling water injected	11.7 hr
Depletion of water in Calandria tank	-
2.6 m above basement floor	158.4 hr
Maximum flooding level (m)	
2.62	

The number of Calandria tank makeup was seven turns. Calandria vault makeup did not inject because the level did not decrease below the setpoint of vault makeup. Also, the reaching time of maximum allowable flooding level was about 158 hours.

As LACs were operated in conservative view of flooding level, integrity of reactor building was maintained.

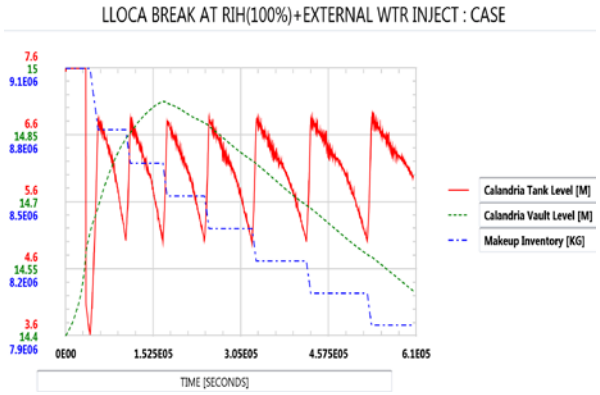

Fig.1. Calandria tank level [m], Calandria vault level [m], and makeup source inventory [KG]

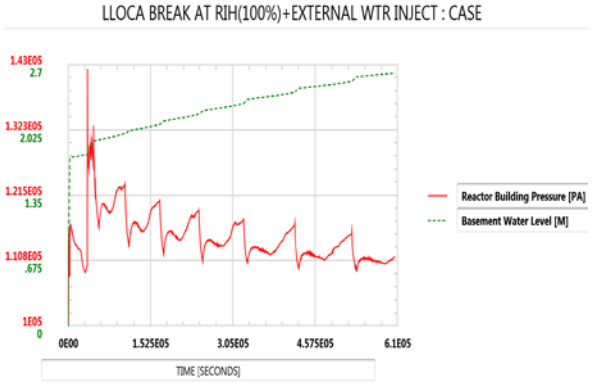

Fig.2. Reactor building pressure [PA] and flooding level [m]

3. Conclusions

The purpose of the analysis is to identify the maximum flooding level during seven days concerning the scenario of LOCA plus external cooling water makeup.

As the results of LOCA base-case analysis, maximum flooding level is about 2.5 m. Also, the maximum flooding level in LOCA plus external cooling water makeup is about 2.62 m, and the reaching time of allowable flooding level takes about 158 hours.

Accordingly, it should be necessary to devise a method for decrease of reactor building water level before 158 hours such as ECCS recirculation operation.

REFERENCES

[1] Wolsong 2,3,4 Final Safety Analysis Report (FSAR)
[2] Wolsong1 External Cooling Water Injection Line Installation design report, KHNP, 2013.
[3] Wolsong1 Severe Accident Management Guidelines, KHNP, 2013