Analysis of Multiple Spurious Operation Scenarios for Decay Heat Removal Function of CANDU Reactors

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1. Introduction

The worst fire broke out in the Browns Ferry Nuclear Power Plant on March 22, 1975 [1]. A fire occurrence in a nuclear power plant has recognized a latently serious incident. Nuclear power plants should achieve and maintain the safe shutdown conditions during and after the occurrence of a fire. Functions of the safe shutdown are five such as the shutdown function, the decay heat removal function, the containment function, monitoring and control function, and the supporting function for CANDU type reactors [2].

The purpose of this paper is to analyze that the decay heat removal function of the safe shutdown functions for CANDU type reactors is achieved under the fire induced multiple spurious operation.

2. Methods and Results

In this section, the scenarios of the fire induced multiple spurious operations (MSO) for the systems used for the decay heat cooling were analyzed. Additionally, Integrated Severe Accident Analysis code for CANDU plants (ISAAC) for determining success criteria of thermal hydraulic analysis was used [3].

Decay heat cooling systems of CANDU reactors are the auxiliary feedwater system, the emergency water supply system, and the shutdown cooling system.

2.1 Design of CANDU Plant for Decay Heat Removal [4]

One motor driven pump in the auxiliary feedwater system provides cooling water to four steam generators and decay heat generated from the reactor core is removed indirectly. The pipes of the auxiliary feedwater system share the main feedwater system except the auxiliary pump and small level control valves (LCV), as shown in Fig.1. Each steam generator has three LCVs that are one small LCV and two large LCVs. One is throttled for steam generator water level and the other is the back-up LCV.

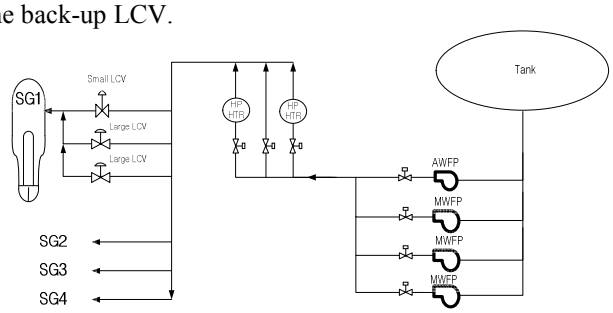

Fig.1. Auxiliary Feedwater System

The emergency water supply system firstly supplies cooling water from dousing tank to steam generators by gravity, if steam generator water level is low. Steam generators should be depressurized because of gravity filling, as shown in Fig.2. Also if dousing tank is unavailable, three emergency water supply pumps (EWSP) operate for injecting into steam generators from the reservoir.

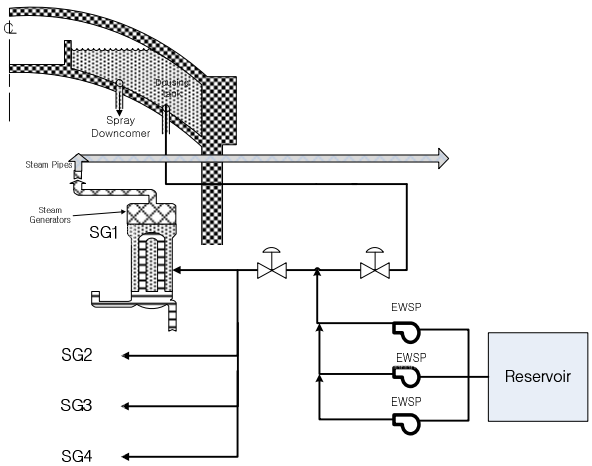

Fig.2. Emergency Water Supply System

The shutdown cooling system can directly remove the decay heat and is composed of two shutdown cooling pumps (SDCP) and two heat exchangers (Hx). The shutdown cooling system can be connected in hot standby mode. Each SDCP is pumped from reactor outlet headers (ROH) to reactor inlet headers (RIH).

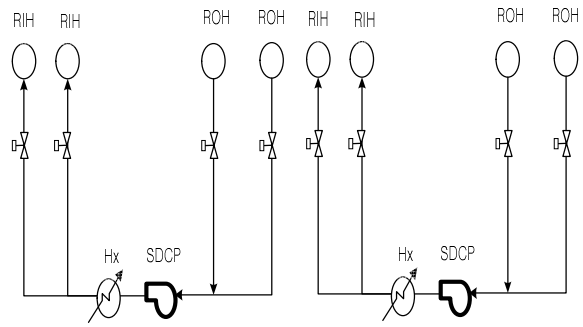

Fig.3. Shutdown Cooling System

2.2 Analysis of Thermal Hydraulics

The assumption for the analysis using ISAAC was that reactor at 100% power was tripped for simulation of the safe shutdown progression. The goal of the

analysis confirmed whether cold shutdown condition can be achieved or not.

If the auxiliary feedwater system for the decay heat removal function was blocked, cold shutdown conditions failed in 2.7 hours. If two steam generators of four steam generators were available, cold shutdown conditions were maintained, as shown in Fig.4.

The next analysis was that cooling water in the dousing tank injected into steam generators by gravity. CANDU reactors designed the emergency water supply system instead of the turbine driven feedwater pumps. As shown in Fig.5, the depletion of dousing tank was about 41.4 hours. If the emergency water supply pumps (EWSP) before the depletion can be used, the cold shutdown conditions would be achieved.

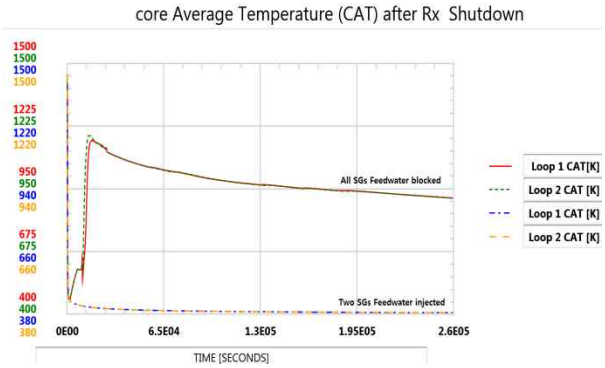

Fig.4. Using Auxiliary Feedwater System

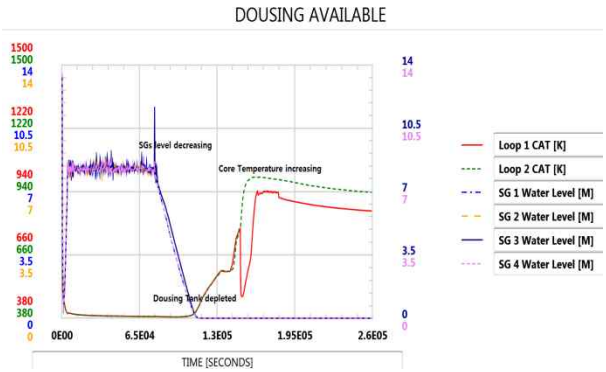

Fig.5. Using Dousing Tank

2.3 Analysis of MSO Scenarios

Selected systems for MSO scenarios of the decay heat removal function were three systems such as the auxiliary feedwater system, the emergency water supply system, and the shutdown cooling system. If fire induced MSOs occurred and the valves more than six isolation valves with two steam generators broke out the spurious operations, the auxiliary feedwater system for the decay heat removal function was lost. Also if one valve for the emergency water supply system and the valves more than two valves for the shutdown cooling system misoperated, decay heat removal function malfunctioned. Accordingly, if total nine valves could be spuriously operated, decay heat removal function for CANDU reactors would be lost completely.

3. Conclusions

A big fire can threat the safety of nuclear power plants, and safe shutdown conditions. The regulatory body in Korea requires the fire hazard analysis including fire induced MSOs.

The safe shutdown functions for CANDU reactors are the shutdown function, the decay heat removal function, the containment function, the monitoring and control function, and the supporting service function. The systems related to the decay heat removal function of the safe shutdown functions are confirmed and MSO scenarios according to the systems such as the auxiliary feedwater system, the emergency water supply system, and the shutdown cooling system also are checked. The number of spurious operations for the auxiliary feedwater system is more than six and that for the emergency water supply system is one. Additionally, misoperations for the shutdown cooling system are more than two. Accordingly, if total nine components could be spuriously operated, the decay heat removal function would be lost entirely.

However, it is virtually impossible that nine components due to fire induced spurious operations are misoperated simultaneously. Therefore, it is expected that the decay heat removal function of CANDU reactors in spite of the fire induced MSO is achieved.

REFERENCES

[1] NEI 00-01, Guidance for Post Fire Safe Shutdown Circuit Analysis, 2011
[2] CAN/CSA N293-12, Fire Protection for Nuclear Power Plants, 2012.
[3] Integrated Severe Accident Analysis code for CANDU plants (ISAAC) Manual, KAERI
[4] Wolsong1 Final Safety Analysis Report, KHNP