Analysis of Multiple Spurious Operation Scenarios for Reactor Shutdown Function of CANDU Reactors

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1. Introduction

Regulatory body of nuclear safety in Korea amended the technical standard for Fire Hazard Analysis (FHA), in 2015 [1]. Safety shutdown analysis in the document should include an analysis of multiple spurious operations (MSO). Accordingly, selection of MSO scenarios for the spurious operation analysis should be preprocessed, due to no generic MSO scenario lists of PHWR [2]. A fire occurrence in a nuclear power plant has recognized a latently serious incident. Nuclear power plants should achieve the safe shutdown conditions during and after a fire. Functions of the safe shutdown are five such as the shutdown function, the decay heat removal function, the barrier to fission product release function, the monitoring and control function, and the supporting function for CANDU type reactors [3].

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

2. Methods and Results

In this section, the scenarios of the fire induced multiple spurious operations (MSO) for the systems used for the reactor shutdown function were analyzed. Additionally, Integrated Severe Accident Analysis code for CANDU plants (ISAAC) for determining success criteria of thermal hydraulic analysis was used [4].

Reactor shutdown systems of CANDU reactors are Shutdown system #1 (SDS#1) and Shutdown system #2 (SDS#2). Also loss of cooling water of heat exchangers in Moderator system was analyzed using ISAAC.

2.1 Design of CANDU Plant for Reactor Shutdown System [5]

CANDU reactors for reactor shutdown have two shutdown systems such as SDS#1 and SDS#2. SDS#1 has twenty eight mechanical shutoff rods actuated by trip signals and SDS#2 has direct liquid poison injection into the moderator. SDS#1 and SDS#2 respectively employ an independent triplicated logic system, which senses the requirement for reactor trip as shown in Fig.1. SDS#1 is allocated to group#1 of special safety systems and SDS#2 is allocated to group#2, which the two groups are separated from each other. Also each of the shutdown systems basically achieves the functional and geometric independence. The shutdown systems are designed with three independent channels and activated by the two out of three channels.

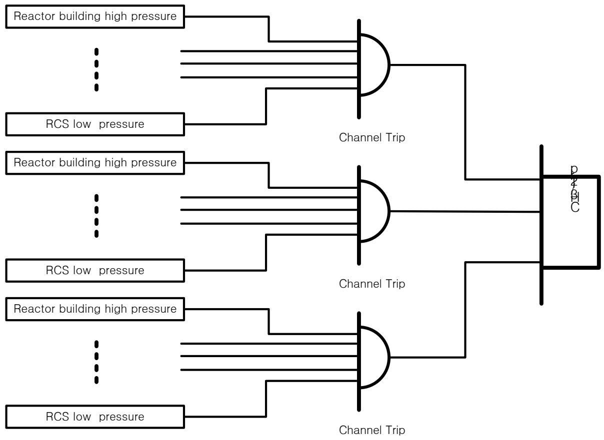

Fig.1. Reactor Trip Logic of SDS #1 & SDS#2

SDS#2 injects a neutron absorbing liquid (gadolinium) directly into the moderator in the reactor core. A schematic of the SDS#2 is shown in Fig.2. The SDS#2 is composed of six poison tanks and six poison injection lines, a single helium supply tank containing high pressure helium, and six quick opening valves. Six quick opening valves are fail open (FO) type and vent valves are fail closed (FC) type.

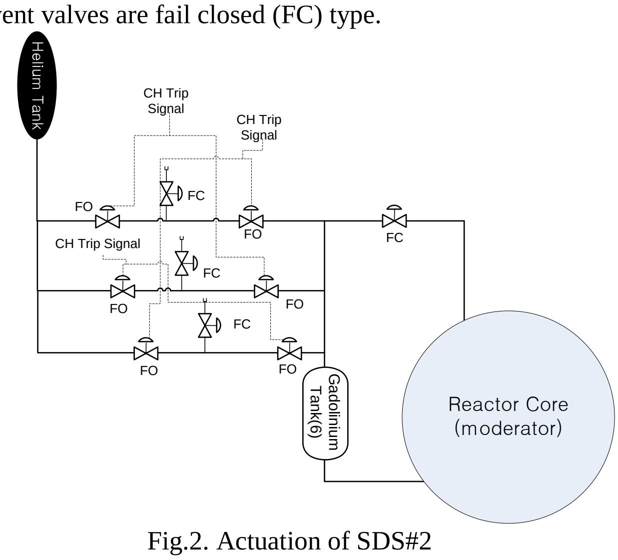

Fig.2. Actuation of SDS#2

2.2 Analysis of Thermal Hydraulics for Moderator System

The one of the SDS#1 trip variables is Moderator High Temperature (MHT) parameter and the parameter is not SDS#2 trip variables. Accordingly, if more than two moderator temperature transmitters and moderator heat exchanger (Hx) cooling simultaneously fail in terms of fire-induced MSO, reactor shutdown function cannot be maintained. Loss of Recirculated Cooling Water (RCW) for moderator heat exchangers could occur if more than four components for flow path block due to MSO would be faulted as shown in Fig.3.

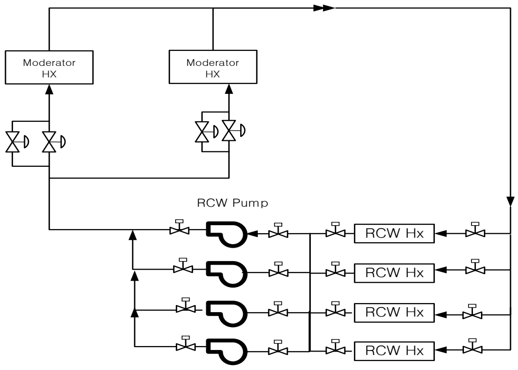

Fig.3. Schematic of Moderator Hx Cooling System

Moderator temperature was analyzed in cases of normal conditions and shutdown conditions using the ISAAC. In case of normal conditions, moderator temperature was increased up to 132℃ and reactor scram was activated by reactor coolant system (RCS) high pressure at 2,523 sec as shown in Fig. 4. In case of shutdown conditions, moderator temperature was increased up to 84℃ and was not reached up to trip setpoint of MHT as shown in Fig. 5.

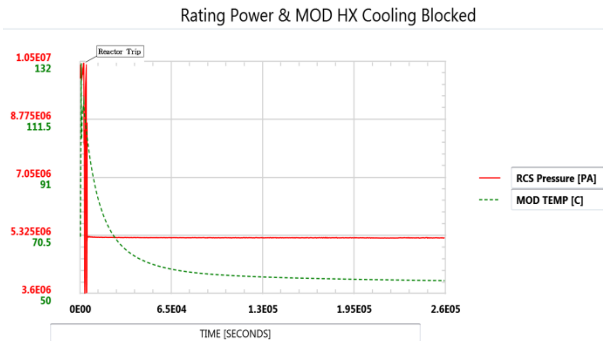

Fig.4. Moderator Temperature and RCS Pressure in case of Normal Conditions

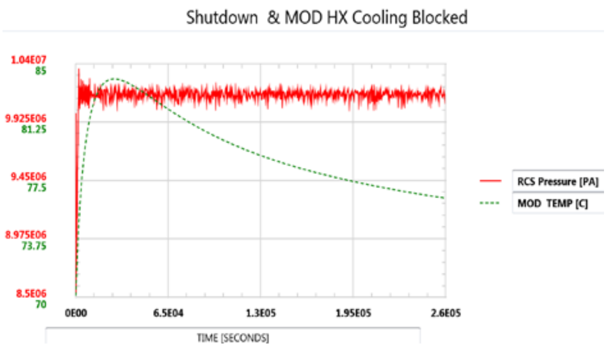

Fig.5. Moderator Temperature and RCS Pressure in case of Shutdown Conditions

2.3 Analysis of MSO Scenarios

Selected systems for MSO scenarios of the reactor shutdown were three systems such as SDS#1, SDS#2, and moderator system. If fire induced MSOs of more than two channels in the shutdown systems (SDS#1 and SDS#2) occurred respectively, the reactor shutdown function of the safe shutdown functions could be lost. However, the triplicated channels are independent and SDS#1 and SDS#2 are functional and geometric independence due to SDS#1 allocated into group#1 of special safety systems and SDS#2 allocated into group#2. Though two MHT transmitters of SDS#1 trip parameters and four components in moderator Hx cooling water system were malfunctioned, reactor shutdown function was maintained as shown in the results of the analysis. If more than three quick opening valves were closed in spite of SDS#2 trip signals due to MSO, reactor shutdown function of SDS#2 could be challenged.

3. Conclusions

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 barrier to fission product release function, the monitoring and control function, and the supporting service function. The systems related to the reactor shutdown function of the safe shutdown functions are confirmed for MSO scenarios according to the systems such as SDS#1, SDS#2 and moderator system. Additionally, spurious operation components for the moderator Hx cooling system are more than four.

However, it is expected to be impossible that SDS#1 and SDS#2 simultaneously fail to scram the reactor because SDS#1 and SDS#2 are functional and geometric independence each other. For further work, cable routines of SDS#1 and SDS#2 will be checked in detail under consideration of these insights.

REFERENCES

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[5] Wolsong2 Final Safety Analysis Report, KHNP