Development of an Analysis Method for a Steam Generator Tube Rupture Accident of an Integral Type Reactor

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1. Introduction

The integral type reactor, a small sized integral type pressurized water reactor is one of the advanced types of small and medium sized reactors [1]. The Steam Generator (SG) is one of the major reactor components in the integral type reactor. The heat that is generated in the core is transferred to the secondary system through the steam generator. The SG cassette consists of a feedwater nozzle, feedwater module pipes, feedwater headers, helical tubes, steam headers, steam module pipes and steam nozzle. The definition of a SG Tube Rupture (SGTR) accident in the integral type reactor is meant to be one helical tube rupture of a SG in the reactor vessel. From this analysis, we can obtain confidence in the safety of the integral type reactor for the SGTR accident.

2. Analysis Methods

The analysis method of a SGTR was developed by using the TASS/SMR code [2]. The ABAQUS module is used for a calculation of the fuel temperature [3]. The definition of a SGTR in the integral type reactor means one helical tube rupture of a SG in the reactor vessel. The penetration parts of the reactor vessel are the subsection pipes of the feedwater lines and the main steam lines. They consist of 12 pipes respectively and one pipe has 6 module pipes. These 6 module pipes have 96 helical tubes with 7 mm diameter in a SG. The helical tubes in a reactor vessel act as a protective barrier for any radioactivity propagation from the primary to the secondary system. If a SGTR occurs, there are complex thermal hydraulic phenomena, as well as, a leakage of the break flow to the secondary system.

The major concern of a SGTR analysis is not the minimum Critical Heat Flux Ratio (CHFR) but the maximum integrated break flow from the primary to the secondary side of the SG. Therefore the break area causing the maximum accumulated break flow is investigated for this reason. The SGTR accident is classified as limiting condition accidents in the Safety Related Design Basis Events (SRDBE) for the integral type reactor.

One helical tube rupture in a SG is the initiating event. The fluid in the secondary system is mixed with that of the primary system which includes a radioactivity level. The mixed fluid is continuously sent to the turbine until the main steam isolation valve is closed. This radioactivity can be released to the environment by the air ejector in a condenser after sending it to the condenser. The air ejector is used for a release of the noncondensible gas to the atmosphere. Actually the reactor trip signal will be actuated by the radioactivity detectors on the steam lines. This signal indicates a high level leakage of radioactivity from the secondary system.

For the conservative result, a reactor trip signal by an operator is used by not taking credit for a signal of a high level radioactivity at the secondary system in the beginning. The system is tripped after 30 minutes from the initiating event by the operator trip signal. After signaling a reactor trip, the SGs are isolated by the feedwater and the main steam isolation valves. And the SGs are connected to the Passive Residual Heat Removal System (PRHRS). The PRHRS removes the decay heat by a natural circulation. The pressure of the Reactor Coolant System (RCS) is continuously decreased according to a leakage of the coolant to the secondary system.

The parameters of concern for this study are the integrated break flow from the primary to the secondary system and the fuel integrity. In a view of the break flow, a smaller break area creates a larger integrated amount through the main steam lines. Because the small break area brings about a delay of the reactor trip time. One stuck rod having the largest reactivity is assumed. The Loss Of Offsite Power (LOOP) is not considered for the increase of the integrated break flow. The integrated break flow is increased by the MCP on No LOOP condition.

3. Analysis Results

A sensitivity study for the break size is done to find the maximum integrated break flow. The longest time case until a reactor trip gives the maximum integrated leakage amount. As a result, the determined initial conditions are a high core power, high PZR pressure, high primary flow and high coolant temperature. In the double ended break case, the integrated break flow is rather small because the reactor trip signal for the low primary system pressure occurs early. The smaller break size creates a greater integrated break flow due to a delay of the reactor trip signal. The higher core power and the high speed of the MCP produce a greater integrated break flow as shown in

Figure 1. The least negative coefficient for the moderator temperature and the most negative coefficient for the Doppler reactivity are used.

The primary system pressure is decreased continuously by a leakage of the coolant to the secondary system during the transient. The initial pressure is the maximum primary system pressure in Figure 2. The RCS pressure is stabilized by the PRHRS after a reactor trip. The CHFR decreases by the feedback effect of the reactivity during an initial time period. The hottest temperature of the fuel rod as shown in Figure 3 is below the design set point, 606 ^{o}C.

4. Conclusion

The development of an analysis method for a conservative calculation for the SGTR accident in an integral type reactor is performed by using the TASS/SMR code. The maximum integrated break flow for the SGTR accident is generated at 16% of the tube section area. For the double ended tube break, the integrated break flow is smaller because the reactor trip signal occurred at an early stage. A large break size advances the time of a reactor trip signal, which is generated by a low PZR pressure and a small break size delays it, which is generated by an operator's action. Also, the most sensitive parameter is the break size from a maximum integrated break flow point of view.

The natural circulation in the RCS and the PRHRS is well established after the reactor trips and it is enough to ensure a stable plant shutdown state. Also, it was observed that the safety features of the integral type reactor design carried out their functions well.

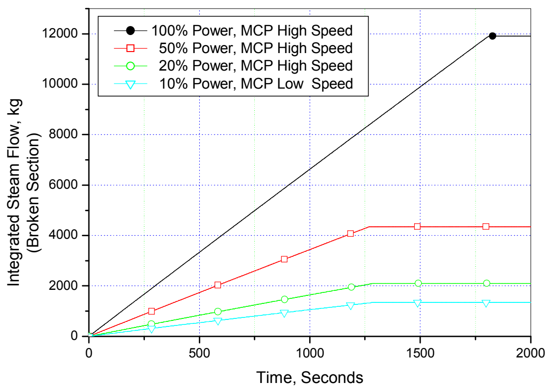

Figure 1. A higher power and a high speed of the MCP conditions cause the integrated break flow to be greater. The break size is used as 16% of the double ended break of a helical tube.

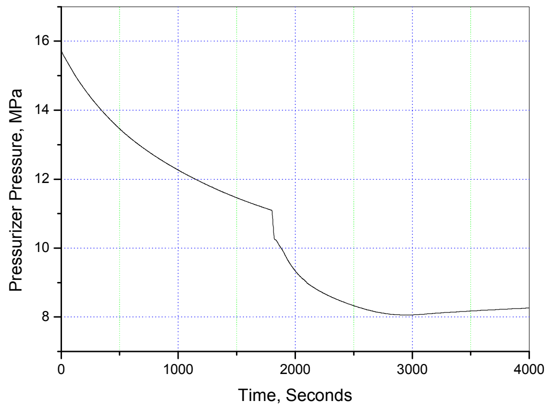

Figure 2. The pressure at the end cavity of a PZR is decreased by a SGTR from the beginning. The decreasing rate is accelerated by the actuation of the PRHRS temporarily.

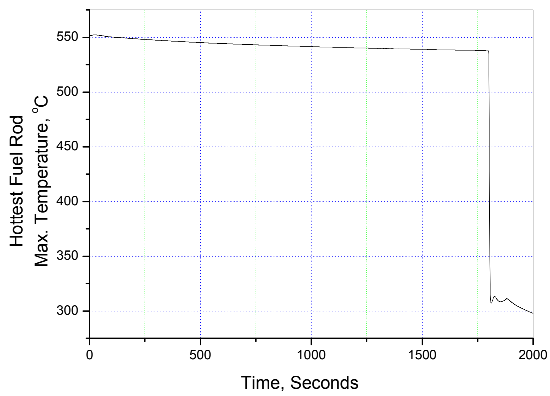

Figure 3. The hottest temperature of the fuel rod is the temperature at the starting point. The temperature is less than 606 **^{o}C** throughout the whole transient.

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