Development of an Analysis Method for the SG Cassette Module Pipe Break Accident Analysis of an Integral Type Reactor

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1. Introduction

The integral type reactor, a small sized integral type pressurized water reactor with a rated thermal power of 65.5 MWt 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 cassette Module Pipe Break (SGMPB) accident in the integral type reactor is meant to be one module pipe break of a SG in the reactor vessel. From this analysis, we can obtain confidence in the safety of the integral type reactor for the SGMPB accident.

2. Analysis Methods

The analysis method of a SGMPB was developed by using the TASS/SMR code [2]. The ABAQUS module is used for a calculation of the fuel temperature [3]. The analysis of a SGMPB was performed to identify the minimum Critical Heat Flux Ratio (CHFR), and the parameters of concern are the fuel integrity and the system pressure. The SGMPB accidents are classified as limiting condition accidents in the Safety Related Design Basis Events (SRDBE) for the integral type reactor.

The SG cassette module pipes in a reactor vessel act as a protective barrier for any radioactivity propagation from the primary to the secondary system. One feedwater inlet module pipe break in a SG is the initiating event. The penetration parts of the reactor vessel are the subsection pipes of the feedwater lines and the main steam lines. 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 a conservation of the result, the system is tripped by a low Pressurizer (PZR) pressure trip signal after not taking into account the signal of a high level radioactivity in the secondary system in the beginning. 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.

One stuck rod having the largest reactivity and Loss Of Offsite Power (LOOP) are assumed for an analysis of the conservative SGMPB analysis. As a result of a LOOP the Reactor Coolant Pump (RCP) does not supply coolant to the RCS after a reactor trip. A transient takes place in a more conservative environment with the above conditions.

3. Analysis Results

The sensitivity study of a SGMPB for the various initial conditions with a double-ended break is performed from a fuel integrity viewpoint. As a result, the determined initial conditions are a low primary flow, high core power, high PZR pressure and a high coolant temperature. The least negative Doppler reactivity coefficient and the most negative moderator temperature coefficient create severer results. The reactor trip signal set by the low PZR pressure is generated at 60 seconds after the initiating event occurs.

According to an over-cooling due to a mismatching of the heat generation in the core and the heat removal in the SG, the coolant temperature at the SG inlet decreases from the beginning of the transient. Thus, the core power is increased by the negative reactivity characteristics of the coolant. Figure 1 shows that the core power has a maximum value at 43 seconds of 120% of the nominal power.

The RCS pressure decreases continuously by a leakage of the coolant to the secondary system during the transient. The initial pressure, 15.75 MPa, is the maximum RCS pressure as shown in Figure 2. The RCS pressure is stabilized by the PRHRS after a reactor trip. The pressure at the broken part of a SG is increased by the incoming flow from the RCS during an initial time period. By the initiation of the PRHRS, the secondary pressure maintains a balance with the pressure of the RCS.

The CHFR decreases by the feedback effect of the reactivity during an initial time period. The minimum CHFR is found to be 1.77 before a reactor trip at 41 seconds in Figure 3. The hottest temperature of the fuel rod is 568 ^{o}C.

4. Conclusion

The development of an analysis method for a conservative calculation for the SGMPB accident in an integral type reactor is performed by using the TASS/SMR code. The minimum CHFRs are maintained at over 1.3, which is one of the acceptance criteria limits, during a transient. The hottest temperatures of the fuel rod are far less than the temperature of the design limit throughout the transients [4]. The natural circulation in the RCS and the PRHRS is well established during the transients and it is enough to ensure a stable plant shutdown state after reactor trip. Also, it was observed that the safety features of the integral type reactor design carried out their functions well.

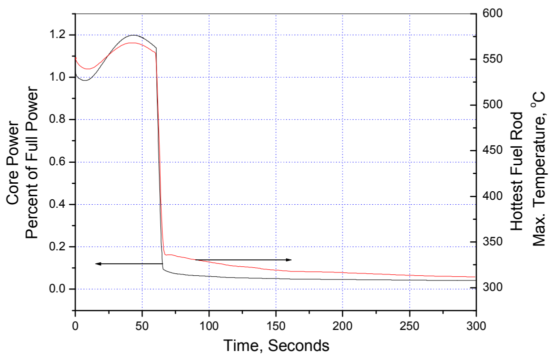

Figure 1 Core power change of SGMPB

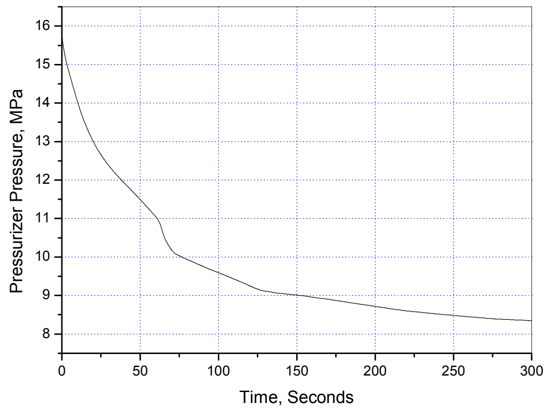

Figure 2 Pressurizer pressure change of SGMPB

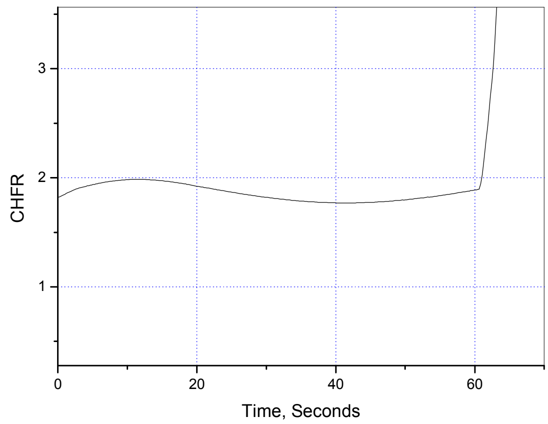

Figure 3 CHFR change of SGMPB

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