Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Risk Reduction Effects Due to the Start Time Extension of EDGs in OPR-1000

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1. Introduction

Under the condition that the ECCS rule in Korea will be revised based on the new U.S. 10 CFR 50.46, the risk impact due to the EDG start time extension is analyzed in the present study. This paper is composed of 6 sections. In the section 2, the LOCA break size that cannot be mitigable under the condition of extended EDG start time is obtained from the thermal hydraulic analysis. The section 3 discusses the frequency of the immitigable LOCA and the probability of the LOOP given a LOCA. In the section 4, the effect of the EDG start time extension on its failure probability is discussed with a qualitative manner. Finally, the whole risk change due to the EDG start time extension is calculated in the section 5 with the conclusions given in the section 6.

2. Determination of Immitigable LOCA Break Size

Thermal/Hydraulic (T/H) analysis was performed to investigate the reactor transient behaviors given that the EDG start time is extended. The amount of EDG start time extension was estimated as about 10 minutes through the interviews with the operators of OPR-1000.

MARS which was developed by KAERI (Korea Atomic Energy Research Institute) was used as the best-estimate T/H system analysis code [1].

As shown in the figure 1, if the break size is larger than 0.4826 m (19 inch), the ECCS of OPR-1000 cannot mitigate the core damage under condition of the EDG start time of 10 minutes.

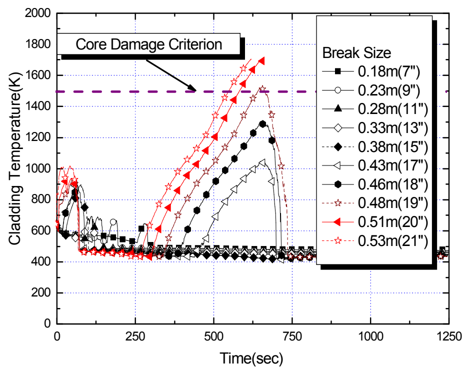

Figure 1 Reactor Core Hottest Cladding Temperatures according to Pipe Break Sizes

3. LOCA Frequency and Probability of LOOP given a LOCA

To estimate the CDF increase by immitigable LOCA, we need the information on the LOCA frequency as a function of pipe break size and the LOOP probability given a LOCA.

3.1 LOCA Frequency Distribution

Recently, NRC has finished a study of new estimations of LOCA frequencies using the expert elicitation process [2]. It was aimed at providing technical basis for the new ECCS rule (10 CFR 50.46). Service history data and the insights from the probabilistic fracture mechanics (PFM) with the knowledge of plant design, operation and material performance were consolidated to provide LOCA frequency as a function of break size.

The present study used these results for the frequency estimation of immitigable LOCA break size. The figure 2 shows the estimation result for immitigable LOCA size according to the years of a NPP operation in a PWR.

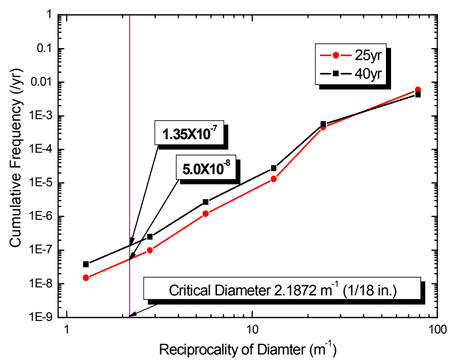

Figure 2 Cumulative LOCA Frequency for PWR (NRC, 2005)

3.2 Simultaneous LOOP given a LOCA

Recently, EPRI and USNRC independently performed the study of estimation for the probability of LOOP given a LOCA [3, 4]. EPRI used an expert elicitation process based on the service history data while USNRC used a systematic approach based on the fault tree method.

In Korea, such a quantitative analysis for the LOOP probability given a LOCA has not been performed yet. In the present study, since there was no study for Korean-specific LOOP probability, the results of

USNRC is used as the LOOP probability given a LOCA for OPR-1000.

4. OPR-1000 Core Damage Risk Changes

5.1 CDF increase by immitigable LOCA

The CDF increase by immitigable LOCA can be estimated quantitatively using the results in section 3. Since the immitigable LOCA may contribute to the CDF under the simultaneous LOOP, the CDF by immitigable LOCA is can be given as follows.

$$CDF_{BLOCA/LOOP} = f_{BLOCA} \cdot P(LOOP|LOCA = .TRUE.) \quad (1)$$

Where,

$CDF_{BLOCA/LOOP}$ = core damage frequency of immitigable LOCA

f_{BLOCA} = frequency of immitigable LOCA

$P(LOOP|LOCA = .TRUE.)$ = probability of LOOP given a LOCA

For the plant years of 25 and 40, the CDF of 3.24E-9 and 1.2E-9 were derived from the results of section 3 respectively.

5.2 CDF decrease by EDG availability improvement

OPR-1000 has three EDGs for the prevention of the station black out (SBO) accident. Since OPR-1000 has three EDGs and the PSA model for OPR-1000 uses a single EDG failure probability for all EDG, CDF can be expressed as follows:

$$CDF_{tot} = CDF(0) + d_1 Q + d_2 Q^2 + \cdots + d_n Q^n \quad (2)$$

Where $CDF(0)$ is the sum of MCSs which has no EDG failure events and Q is failure probability of an EDG. The coefficient d_i in Eq. (2) can be obtained from the MCSs in which *i* EDG failures event included

For the quantification, the present study used the KIRAP code [5] which was developed by KAERI and uses FTREX [6] as the quantification engine in the KIRAP code. Under the truncation limit of 1.0E-11 for the MCSs, KIRAP shows over 3500 MCS which include EDG failure events.

To obtain the risk impact due to the improvement of the EDG availability, the CDF change can be given using Eq. (3) in the sense of Birnbaum.

$$\Delta CDF_{EEDG} = \left(CDF(0) + d_1 Q_{BASE} + d_2 Q_{BASE}{}^2 + d_3 Q_{BASE}{}^3\right) - \left(CDF(0) + d_1 Q + d_2 Q^2 + d_3 Q^3\right) \quad (3)$$

Where ΔCDF_{EEDG} is the amount of CDF decrease by EDG availability improvement in failure to start events.

Q_{BASE} is the base EDG probability of failure to start

Figure 4 shows the CDF changes by the EDG unavailability decrease including CDF increase due to immitigable LOCA. From the figure 4, when the EDG availability increase is 1.5E-4 and 5.0E-5 for plant operation year, 25 and 40 respectively, the net CDF is unchanged. However, if the EDG availability increase by the extension of start time is larger than the critical values, the net CDF become decreased.

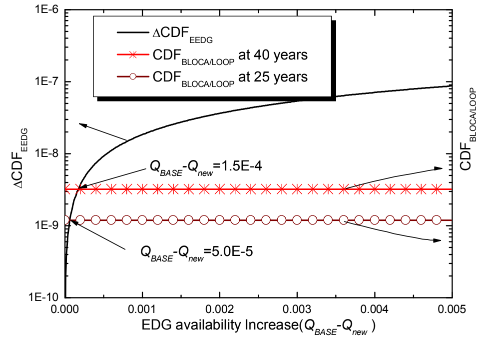

Figure 3 OPR-1000 CDF changes due to EDG start time extension

3. Concluding Remarks

The present study performed the pilot study for the risk change due to the EDG start time extension in OPR-1000. As an overall result, it was found that the whole plant CDF would be reduced if the EDG failure probability is slightly decreased due to the EDG start time extension in OPR-1000. Also, if the precise EDG unavailability reduction can be given as a result of EDG start time extension, more accurate plant CDF change is expected to be analyzed. As a pilot study, this work is expected to contribute to similar work as an Option 3 framework.

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