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Alternative Method for Feedwater Line Break Analysis of OPR1000

Jong Beom Lee* and Sang Yeol Kim
Nuclear Engineering & Technology Institute, Korea Hydro & Nuclear Power Company, Ltd.,
508 Kumbyungro, Yuseong-gu, Daejeon 305-343, Republic of Korea
**Corresponding author: jbdoll@khnp.co.kr*

1. Introduction

Overpressure protection margins for transient accidents have been a growing issue in the Korean nuclear society since the late nineties [1-3]. The most limiting overpressure transient case for OPR1000 is a main feedwater line break (FLB) accident. An alternative method for securing more overpressure protection margins for the FLB of OPR1000 is described herein. The proposed method uses the Korea Non-LOCA Analysis Package (KNAP) method [4] with some modifications in the analysis assumptions. Comparisons of the peak pressure calculations to those of the conventional method and the KNAP method of OPR1000 are presented.

2. Methods and Results

In this section an alternative method for a main feedwater line break analysis is described. The proposed method modifies the original KNAP method with respect to the analysis assumptions. The resultant peak pressure calculations are compared to those of other methods.

2.1 Characteristics of an FLB accident

An FLB is defined as a break in a feedwater line large enough to prevent the addition of sufficient feedwater to the steam generators. If the break occurs in a feedwater line between the check valve and the steam generator, fluid from the steam generator may also be discharged through the break. Moreover, a break in such a location could preclude the subsequent addition of auxiliary feedwater to the affected steam generator. As a result of the poor heat transfer from the primary system to the secondary system, the temperature and the pressure of the primary system increase until the reactor trips. The maximum or peak pressure of the primary system should be limited to within 110% of the design pressure of 2500 psia. A reactor protection system provides trip signals such as high pressurizer pressure, low-low steam generator water level, and high containment pressure.

2.2 Conventional method for OPR1000

In the conventional FLB analysis, the CESEC-III computer code [5] is used to evaluate the plant transient following the FLB. The code describes the plant thermal kinetics and RCS conditions including pressurizer, steam generators, and feedwater system. It also computes operational variables such as pressurizer pressure, pressurizer water level, and reactor coolant average temperature.

In the CESEC-III model, a steam generator is treated as a lumped control volume and the code calculates its water mass by solving mass continuity equations. The level of the steam generator is computed using a look up table of mass, power level and the corresponding water level which is pre-calculated with the CRIEBE code. However, this look up table only indicates the static water level of the steam generator and cannot determine what the water level of the steam generator is during transient conditions. Due to this lack of calculation capability of the code, the trip signal caused by the low-low steam generator water level is not credited in the transient analysis. Reactor trip is assumed to occur when the pressurizer pressure reaches the set point of the high pressurizer pressure trip signal.

The peak pressure calculation is shown in Figure 1. When the FLB occurs, the pressure of the primary system rapidly increases and the pressurizer safety valve (PSV) is opened shortly after the pressurizer high pressure trip at 34.6 seconds. The pressure of the primary system goes up again when the steam generators are dried out and the second opening of the PSV occurs at around 700 seconds. The peak pressure is 2730 psia at 36.9 seconds in this case.

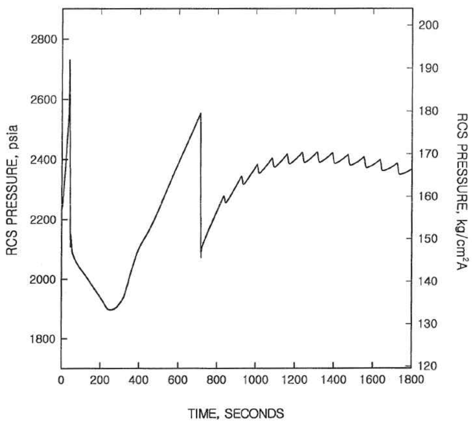

Figure 1. RCS Pressure of Ulchin 3&4 [6]

2.3 KNAP method for OPR1000

In the KNAP method, the RETRAN-3D code is used to calculate the operational variables. Each steam generator is modeled as fourteen control volumes. The look up table of the mass and power level is used in the

KNAP method just as in the conventional method. But the water level of the steam generator is calculated using the bubble rise model inherent in the RETRAN-3D code, which is a combination of semi-empirical relations for gas phase or bubble distribution and a differential equation for the gas mass in a control volume [7].

By using the bubble rise model, the steam generator water level can be calculated directly from the code during both normal and transient conditions. Thus, trip signal caused by the low-low steam generator water level of the unaffected steam generator is used in the KNAP method.

The peak pressure result is shown as a dotted line in Figure 2. Reactor trip occurs when the water level of the unaffected steam generator reaches the set point of the low-low steam generator water level trip at 35.25 seconds, followed by the opening of the PSV. The RCS pressure increases again and the MSSVs are opened to protect against the overpressure of the system. The peak pressure for this case is 2588 psia at 39.25 seconds.

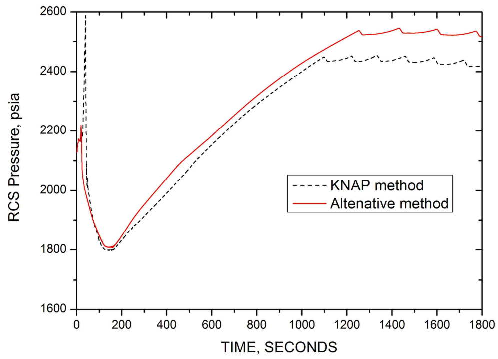

Figure 2. Comparison of the RCS Pressures

2.4 Alternative method for OPR1000

The alternative method for FLB analysis is based on the KNAP method. The same approach as that used in the KNAP method is applied in the alternative method. But, since we are convinced that the water level calculated in the RETRAN-3D is correct, we credited both trip signals coming not only from the unaffected steam generator but also from the affected steam generator. In this case, reactor trip occurs upon the low-low water level trip signal from the affected steam generator.

The solid line in Figure 2 shows the results of the alternative method. After the low-low steam generator water level trip at 15.72 seconds the RCS pressure decreases. The RCS pressure increases again after the dry out of the affected steam generator until the MSSVs are opened. The peak pressure for this case is 2544.63 psia at 1430.5 seconds. An overpressure protection margin of about 43 psi can be achieved by using the alternative method compared to the KNAP method.

It should also be noted that the PSV is not opened in this alternative method. The reason is that the RCS pressure in this case is lower than that in the KNAP case, owing to the early trip time of the alternative method. Since there is no direct release of radioactive materials from the primary system, the radiological consequences will be much smaller than those of other methods. Table 1 summarizes the results for each case.

Table 1. Comparisons of the Results for Each Method

Method	Trip Signal	Trip Time (sec)	Peak Pressure (psia)
Conventional CESEC-III	Pressurizer high pressure	34.60	2730
KNAP	Low-low water level from the unaffected steam generator	35.25	2588
Alternative	Low-low water level from the affected steam generator	15.72	2544.63

3. Conclusions

An alternative method for FLB accident analysis is presented. This method uses realistic assumptions in calculating the water level of steam generators. Peak pressure calculation results are compared to those of other methods. The new method is useful for achieving a better overpressure protection margin and for reducing radiological releases to the environment.

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