The OBE Elimination in Piping Design

Hee-Cheol Cho, In-Yeung Kim, Soon-Chul Yun and Koo-Woun Park

Korea Power Engineering Company, Inc., Korea

ABSTRACT

The Operating Basis Earthquake(OBE) and Safe Shutdown Earthquake(SSE) have been considered in the design of nuclear power facilities as required by the Appendix A to 10 CFR Part 100. However, it is believed that the elimination of the OBE from design of nuclear facility would be necessary for plant optimization since the OBE criterion is too rigid and has excessive conservatism. Studies indicate that the alternate piping designs can exhibit reliability and safety levels equal to or greater than the current analysis methods. The alternate rules for the Earthquake Engineering Criteria have been issued by the Appendix S to 10 CFR 50.

In the System 80⁺ Design, the USNRC reviewed the alternate analysis methods which were proposed to eliminate the OBE based on the EPRI-URD and concluded that those were acceptable as stated in the NUREG-1462. In the Korean Next Generation Reactor(KNGR) developed as an ALWR, a typical piping model was selected to include ASME Classes 1, 2 and 3 piping and analyzed according to the current method as well as the alternate analysis method, specified in NUREG-1462, for comparison.

1. INTRODUCTION

Safety and economic reasons are motivations to apply modern technology to nuclear power plants. Historically, the seismic design of nuclear power plants in the U.S. has included two levels of design earthquake, the Safe Shutdown (or Design Basis) Earthquake (SSE) and the Operating Basis Earthquake (OBE). Appendix A to 10 CFR Part 100 requires that the OBE be equal to at least one half of the Safe Shutdown Earthquake. It also mandates that the plant be analyzed and designed to both the OBE and SSE, and that the plant be shut down in the event that an earthquake exceeding the intensity of an OBE occurs at the plant site.

In addition, contrary to the original intent that the SSE governs the seismic design, the OBE

turns out to govern the seismic design of nuclear plant systems and components in many instances.

In recognition of the above, current regulations which are applicable to the advanced reactor designs (ALWRs) in the U.S. explicitly require only the specification of the Safe Shutdown Earthquake. Specification of an OBE and the associated analyses are not mandated unless the applicant chooses to specify an OBE that is greater than one third of the SSE.

2. CURRENT PIPING SEISMIC DESIGN

Based on the current U.S. regulatory position on the specification of an OBE greater than one third of the SSE, the decision to design for the OBE rests with the applicant for a nuclear power facility. This decision must be based on the probable seismic risk at the plant site and associated probability of a required plant shutdown. For a standard plant design such as the KNGR, therefore, it would be reasonable to eliminate the OBE from the seismic design if the most probable seismic risk at a majority of the potential plant sites will conceivably be no greater than one third of the SSE the standard plant is designed to.

The system 80⁺ standard plant and Advanced Boiling Water Reactor standard plant that received the Design Certification from the NRC in 1997, opted for eliminating the OBE from the design process. The Westinghouse AP 600 standard plant, still in the process of securing the Design Certification from the NRC, also opted for eliminating the OBE. This represents the current trend in the U.S. nuclear industry with regards to new plants, and it is based on extensive earthquake experience data and sound engineering judgement.

Since the KNGR represents the cutting edge of Korean nuclear power technology, it is appropriate that a progressive approach to seismic design, as discussed above, be incorporated in its design. However, as part of the justification necessary for eliminating the OBE from the design, it must be demonstrated that current seismic practice results in an unnecessarily conservative design. The following sections present an analytical basis for such a conclusion.

3. DESCRIPTION OF ANALYTICAL MODEL

The analytical model, shown in Figure 1, consists of 248 nodes, with 6 degrees of freedom per node. This piping system is routed from Shutdown Cooling System outlet nozzle on the Reactor Coolant System (RCS) loop hot leg to the Safety Injection / Shutdown Cooling and Containment Spray Pumps. The piping system has been divided into four parts (A,B,C and D) for analytical convenience.

Figure 2. shows the physical dimensions and restraint locations of the piping system.

The respective constraints of the support type were imposed directly on the nodes of the supported piping. The supports are modeled as infinitely rigid. This may be considered a

conservative assumption. The boundary conditions associated with the supports are presented in the Figure 2. Tables 1 and 2 contain the material and geometrical properties of the piping system, respectively.

Table 1 Material properties of the piping system

Type of Material : Austenitic Stainless Steel SA358
Young's Modulus of Elasticity(E) : 28.3×10^6 psi
Poission's Ratio(ν) : 0.3
Yield strength (S_y) : 21,600 psi
Allowable stress in the hot condition : 16,700 psi

Table 2 Geometrical properties of the piping system

PIPE (in)	PIPE OD (in)	Thickness (in)	Length (ft)
24	24.0	1.218	30.7
20	20.0	1.031	50.8
16	16.0	0.843	348.0
14	14.0	0.750	13.0

Fig 1 Configuration and layout of the analyzed piping

Fig 2 Dimensions and restraint locations of the analyzed piping

4. ANALYSIS DESCRIPTION AND RESULTS

The dynamic response of a piping system induces primary & secondary stress due to seismic loading (OBE / SSE). The OBE and SSE Inertia Loading are the inertia portion of the total loading induced by the OBE and SSE excitation amplified by building response motion, respectively. The subject piping system was analyzed for the aforementioned seismic inertia loads so as to evaluate the responses in terms of the governing loads. Seismic displacement loads were not considered since they typically do not control the design.

The piping system was analyzed using the PIPSYS computer program which utilizes the finite element method of analysis. The piping along with its restraint system was modeled as multi-degree of freedom two-dimensional finite beam elements. The response of the piping system to each one of three mutually perpendicular excitations (North-South, East-West, Up-Down) was calculated in accordance with standard industry practice and regulatory requirements. The seismic response spectra used in the analysis are shown in Figure 3. It should be noted that, in accordance with ASME III Code Case N-411-1, the spectra are based on PVRC damping values. The resulting moments were translated into stresses based on Equation 9 of ASME Section III, NB/NC/ND-3650 which is given below. The effects of pressure, dead weight, other sustained loads, and occasional loads (including earthquake), for which Level B or D Service Limits are designated, must meet the requirements of Equation (9):

$$S_{OL} = B_1 \frac{P_{max} D_0}{2t_n} + B_2 \left(\frac{M_A + M_B}{Z} \right) \leq 1.8S_h \text{ (}\geq 1.5 S_y\text{) for Level B}$$

$$\leq 3.0S_h \text{ (}\geq 2.0 S_y\text{) for Level D}$$

For the KNGR, OBE and SSE loads are defined as Service Level B and D loads, respectively. The nomenclature for the terms included in Equation (9) is defined in Reference 6. Finally, the calculated Equation (9) stresses were graphically plotted so as to provide a visual representation of the OBE and SSE effects for comparative purposes. These graphs are shown in Figure 4 which contains four graphs, each pertaining to the four analytical parts (A, B, C and D). The graphs plot stresses versus physical location on the piping, i.e., node numbers. Solid lines represent Equation (9D) stresses which include SSE loads, while dashed lines represent Equation (9B) or OBE inclusive stresses.

These graphs indicate that, although the difference in ASME allowable stress levels is large (1.8S_h versus 3.0S_h), the actual stresses do not exhibit very large differences between the OBE and SSE load cases. Figure 5 shows the OBE governing rates for the four analytical parts mentioned above. The governing rates reflect the respective margins available for the OBE & SSE load cases.

Fig 3 PVRC Seismic Response Spectra

Fig 4 OBE & SSE Stress Value Comparison

Fig 5 OBE Stress Values Governing Rates (Part A,B,C,D)

5. CONCLUSIONS

The results of the analysis show that eliminating the OBE from the design basis substantially reduces the number of piping supports and the analysis iteration time to achieve the same level of equivalent design margin. As a result, it can be expected that the elimination of the OBE will contribute to improve economy and design simplification. With these new rules, nuclear power plants would be able to remove about 30% of the piping restraints due to seismic inertia effects, which in turn would significantly reduce construction, operating, and maintenance costs. We believe that this would also result in increased the safety of the plants because industry seismic experts hold the position that a flexible structural system will withstand earthquakes far better than a rigid system. Recent earthquake experience has also shown significant problems and failures with structures that are too rigid.

REFERENCES

- (1) G.W. Housner and D.E. Hudson, "Earthquake Research Problems of Nuclear Power Plants," Nuclear Engineering and Design, No.3, 1996.
- (2) U.S. Nuclear Regulatory Commission, "Earthquake Engineering Criteria for Nuclear Power Plants," 10 CFR Part 50, Appendix S, January 1, 1997 Edition.
- (3) N.M. Newmark and W.J. Hall, "Seismic Design Criteria for Nuclear Reactor Facilities," Proceedings 4th World Conference on Earthquake Engineering., IAEA, Santiago, Chile, Vol.II, Section B-4, 1969.
- (4) U.S. Nuclear Regulatory Commission, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," 10 CFR Part 100, Appendix A, last published in November 1973 and recently revised on January 10, 1997.
- (5) J.D. Stevenson, "Rational Determination of the Operational Basis Earthquake and Its Impact on Overall Safety and Cost of Nuclear Facilities," Nuclear Engineering and Design, No.35,1975.
- (6) ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, Class 1,2, and 3, 1992 Edition.
- (7) U.S. Nuclear Regulatory Commission Regulatory Guide 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions," March, 1997.
- (8) USNRC NUREG-0800 "Standard Review Plan", Office of Nuclear Reactor Regulation, Section 3.7.3 "Seismic Subsystem Analysis", Rev.1, July 1981.
- (9) IEEE Standard 344-1987, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations".
- (10) Integrated Piping System Analysis (PIPSYS Program)