Updating of Seismic PSA of Beznau Nuclear Power Plant

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ABSTRACT

This paper describes the on-going project to update the seismic PSA of Beznau Nuclear Power Plant in Switzerland. Beznau is the oldest operating PWR in Europe. It has been reevaluated and upgraded for seismic issues over the last twenty five years. The results of a recent seismic hazard study have prompted an update of the seismic fragility and systems analysis. Detailed probabilistic seismic response analysis, plant walkdown and seismic fragility updates have been completed. Quantification of seismic induced accident sequences is underway.

BACKGROUND

Beznau Nuclear Power Plant owned by Nordostschweizerische Kraftwerke AG of Switzerland is the oldest PWR operating in Europe. Probabilistic safety assessments under full power and shutdown conditions have been carried out for Beznau since the early 1980's. These PSAs included consideration of seismic events although the seismic hazard in Switzerland was generally assumed to be low to moderate. Based on the findings of PSA, several modifications have been done to the plant over the years. Examples of these are the construction of an independent emergency shutdown system (called NOTSTAND), addition of seismic supports for several piping systems, and upgrade of anchorage of electrical equipment and masonry walls.

A complete reevaluation of the seismic hazard at Swiss NPP sites was performed during the last four years, the so-called PEGASOS project (Abrahamson, et al 2002). The study was conducted using the SSHAC methodology (Budnitz, et al 1997) as a Level 4 study and was intended to replace the earlier seismic hazard analyses used in the Beznau PSA. A report with the results of the PEGASOS project was issued in July 2004. These results were evaluated by the Swiss utilities and also by Swiss Nuclear Safety Inspectorate (HSK). A follow up project to improve the results is underway. The Swiss Nuclear Safety Inspectorate (HSK) has required in 2004 a complete update of the Beznau NPP seismic PSA taking into account the PEGASOS hazard analysis results and the current status of the plant.

SEISMIC PSA SCOPE

NOK has initiated the project to update the seismic PSA of Beznau NPP in 2005 and has engaged the services of ABSG Consulting Inc (ABS Consulting) for seismic fragility evaluation. The objectives of this update are:

- Conduct a Level 1 and Level 2 PSA study for full –power modes and a Level -1 PSA study for low power and shutdown modes.
- Incorporate the preliminary results of the PEGASOS hazard study.
- Perform the seismic PSA in conforming to the Capability Category II requirements of the ANS Standard (ANS, 2007).
- Develop a comprehensive documentation of the study.

FRAGILITY PARAMETER

Initial thinking was to develop fragilities expressed in terms of average spectral acceleration (between 2.5 Hz and 8 Hz) in free field at the foundation level of the reactor building. A review of the uniform hazard spectra for the three distances (within 10 km, between 10 km and 25 km, and more than 25 km designated as D1, D2 and D3 respectively) at annual frequency of exceedance of 1 E-03, 1E-04 and 1E-05 showed remarkable similarity in the spectral shape and all the spectra peak at 5 Hz (ProSeis, 2006). In the probabilistic seismic response analysis, the impact of the uncertainty in the spectral shape was considered through Latin Hypercube sampling. Therefore, there will be no loss of accuracy if the fragility is referenced to 5 Hz spectral acceleration avoiding the need for generating the seismic hazard curves in terms of average spectral acceleration. Seismic hazard curves in terms of 5 Hz spectral acceleration for the three distances D1, D2 and D3 are already available.

Further, it was concluded that use of only one spectral shape instead of the spectral shapes of the disaggregated motions is justified as discussed below.

In the development of seismic fragilities, the input spectral shape is the controlling element for the evaluation of the seismic demand. Typically, the spectral shapes corresponding to earthquakes occurring at different distances from the site in question could be quite different due to the predominant low frequency wave's content in the distant earthquakes and the predominant high frequency waves in the near earthquakes. However, according to the results from the PEGASOS project, the spectral shapes for earthquakes at different distances are practically identical. This is shown in Figures 1 and 2 where the total and disaggregated horizontal spectral shapes normalized to spectral ordinate at 5 Hz have been plotted. Thus, it is clear that a seismic analysis performed using any of the spectra, total or disaggregated, when the input is scaled to the same level will produce, for all practical effects, the same seismic responses. Furthermore, and since the seismic demand will be obtained by probabilistic analysis, any small differences between the various spectral shapes will be covered by the differences in the spectral shapes of the thirty input motions used in the probabilistic analysis.

A detailed probabilistic seismic response analysis of the Beznau NPP buildings has been completed by modeling the soil-structure interaction effects and actual soil conditions at the site. State-of-the-art methods and computer codes (SASSI, ANSYS) were used to generate probability distributions of floor responses at different locations of the buildings. Details of the probabilistic seismic response analysis are provided in a companion paper by Tinic, et al (2007).

SEISMIC EQUIPMENT LIST AND PLANT WALKDOWN

NOK has developed the Seismic Equipment List (SEL) following the requirements of the ANS Standard and the existing configuration of the plant systems including the Notstand. This list comprising of structures, reactor system components, mechanical and electrical equipment and piping and cable tray systems is about 1000. It is to be noted that that Unit 2 of the two-unit plant is modeled for seismic PSA.

During the outages of Units 1 and 2 in June –August 2006, NOK and ABS Consulting engineers spent over four weeks examining the different equipment items on SEL, completed the checklists (called SEWS) and compiled a walkdown database comprising of checklists, notes and photographs. In general, the walkdown focused on the seismic ruggedness of the equipment, anchorage, mounting of internal devices and potential systems interaction concerns.

SEISMIC FRAGILITY EVALUATION

Seismic fragility evaluation took the following into account:

- There have been several structural modifications to the plant since the original design.
- Since the plant specific ground response spectrum selected for this analysis (i.e., uniform hazard spectrum at 10-5 annual exceedance frequency) has higher amplification compared to the R.G. 1.60 ground response spectrum, the responses that the structures and equipment see are generally higher than used in the earlier seismic PSAs.
- Plant specific concrete ultimate strength in the current aged condition has been obtained by NOK using core samples; this is much higher than the nominal design strength.
- In the previous seismic PSA, conservative estimation of fragilities of structures and equipment was sufficient since the estimated seismic hazard at that time was low. With the current increased seismic hazard estimate, it is important to have realistic seismic fragilities.
- There has been several improvements in the seismic fragility methodology (e.g., evaluation of sliding capacity and calculation of shear wall strength).
- The new seismic response analysis resulted in the identification of different failure modes in the structures.

A detailed probabilistic analysis of potential soil failures (i.e, liquefaction and soil settlement) has been performed to conclude that these failures have extremely low probabilities of occurrence in the range of earthquakes considered for this seismic PSA update.

Using the seismic response analysis results and the findings of the walkdown, seismic fragilities of structures and equipment that are realistic and reflect the existing condition of the plant are being calculated. These fragilities will be input into the updated model of the Beznau PSA system to obtain estimates of the seismic induced core

damage frequency and large early release frequency. The ultimate goal is to obtain a seismic PSA of the plant that is usable for future risk-informed applications as well as to identify any seismic upgrades for further enhancement of the seismic safety of the plant. The study will be completed in late 2007 and the preliminary findings would be presented at the SMiRT Conference in Toronto.

REFERENCES

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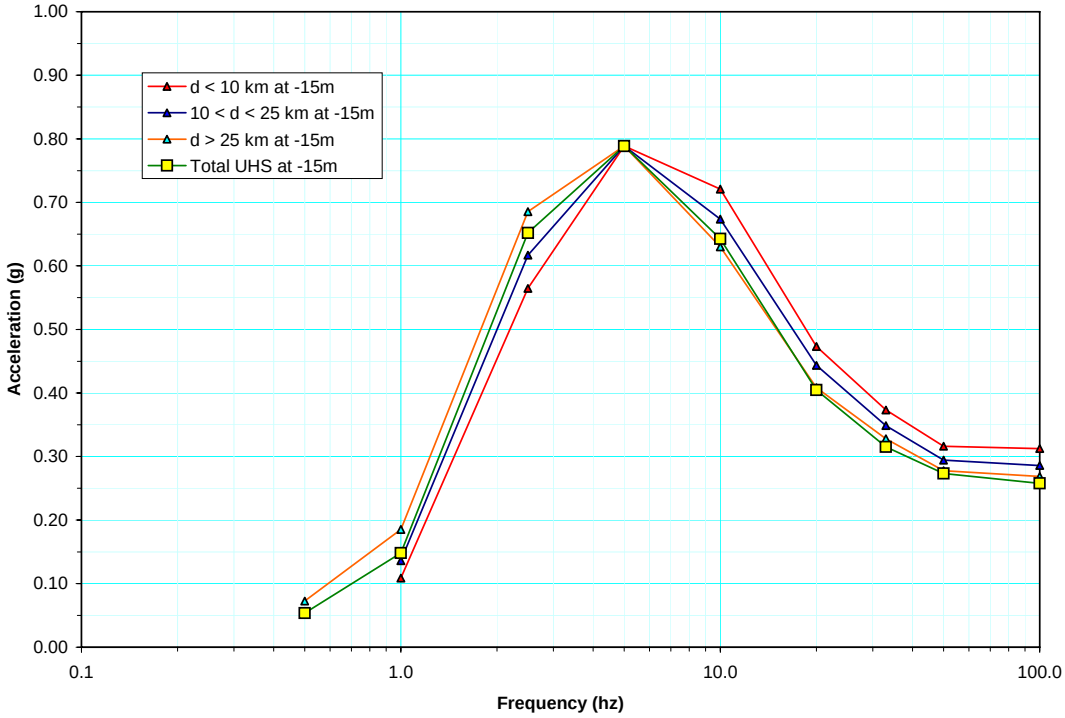

Figure 1. Normalized (5 Hz) Median UHS at Elevation -15m
Annual Probability of Exceedance 1.0E-04

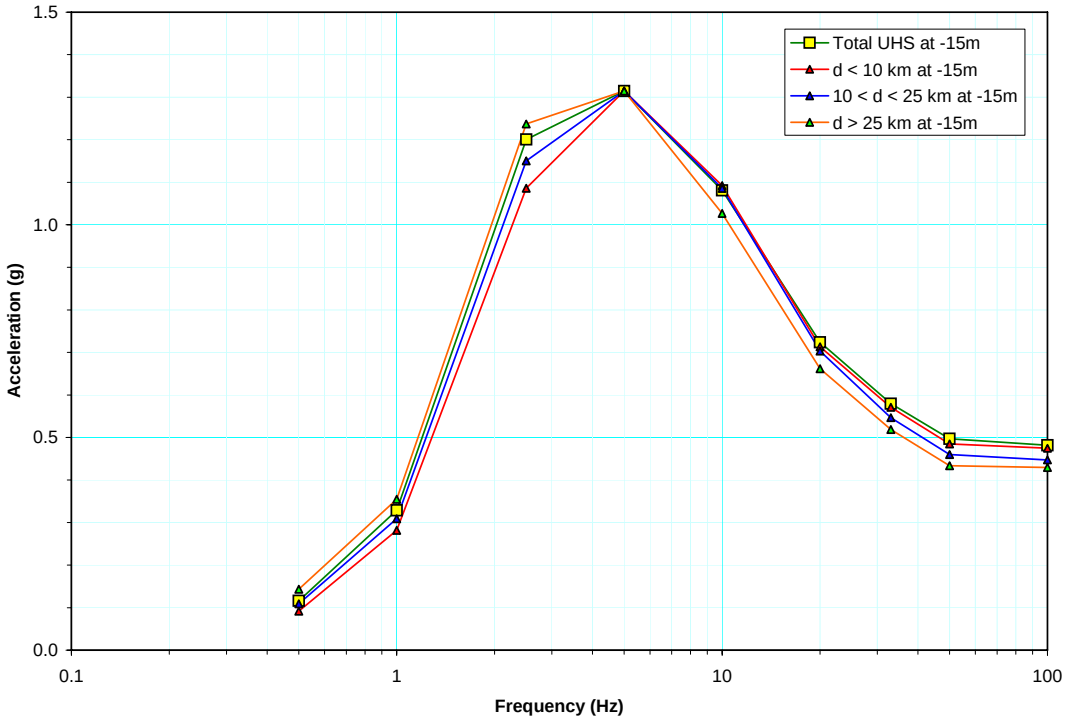

Figure 2. Normalized (5 Hz) Median UHS at Elevation -15m
Annual Probability of Exceedance 1.0E-05