September 12, 2003

MEMORANDUM TO: Ashok C. Thadani, Director
Office of Nuclear Regulatory Research

FROM: Nilesh C. Chokshi, Chairman ***/RA/***
Reactor Generic Issue Review Panel
Office of Nuclear Regulatory Research

SUBJECT: RESULTS OF INITIAL SCREENING OF GENERIC ISSUE 194, "IMPLICATIONS OF UPDATED PROBABILISTIC SEISMIC HAZARD ESTIMATES"

In accordance with Management Directive (MD) 6.4, "Generic Issues Program," the Generic Issue Screening Panel has completed the initial screening of Generic Issue (GI) 194, "Implications of Updated Probabilistic Seismic Hazard Estimates," and has concluded that the issue does not represent a new safety concern (see Attachment 1). GI-194 addresses the concern for the adequacy of existing deterministic seismic design criteria for the licensing basis of plants in the East Tennessee Seismic Zone.

The panel found that the concerns have been addressed through previous programs and recommends that the issue be excluded from further analysis. Please note that the panel's findings rely on the fact that the relay chatter issue has been properly disposed of in the IPEEE Program, i.e., when necessary, low-ruggedness relays have been replaced by higher capacity relays. In addition, the panel report also notes that, when the ongoing US Geological Survey (USGS) seismic hazard study is completed, the results should be evaluated to verify that the frequency characteristics of the ground motions are not significantly different from those on which the panel's evaluation was based. Your approval of the panel's recommendations is required so that RES can proceed to the next step of the MD 6.4 process.

Attachments:
1. Panel Report on Initial Screening of GI-194
2. Analysis of GI-194

Approved: /RA/ Date: 9/20/2003
Ashok C. Thadani, Director, RES

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PANEL REPORT ON INITIAL SCREENING OF
GI-194, "IMPLICATIONS OF UPDATED PROBABILISTIC SEISMIC HAZARD ESTIMATES"

Panel (3): Nilesh C. Chokshi (MEB/DET/RES), Chairman
Arthur J. Buslik (PRAB/DRAA/RES)
Clifford G. Munson (EMEB/DE/NRR)

The above panel met from 1:07 p.m. to approximately 3:00 p.m. on January 28, 2003, in Room T10-C2, Two White Flint North, Rockville, Maryland, to conduct an initial screening of Generic Issue (GI) 194, "Implications of Updated Probabilistic Seismic Hazard Estimates," in accordance with Management Directive 6.4, "Generic Issues Program." Attending the meeting were Harold J. VanderMolen (REAHFB/DSARE/RES), Ronald C. Emrit (REAHFB/DSARE/RES), Andrew J. Murphy (ERAB/DET/RES), Goutam Bagchi (DE/NRR), and Donald G. Harrison (SPSB/DSSA/NRR). Harold VanderMolen gave a brief explanation of the MD 6.4 process prior to the discussion of the issue.

Discussion

The discussion centered around an analysis of the GI (an earlier version of Attachment 2) by Donald Harrison that was sent to the panel members on December 10, 2002, for review in preparation for the meeting. After a general discussion of this analysis and the latest USGS hazard curves for the Eastern Tennessee Seismic Zone (ETSZ), the panel discussed the IPEEE process which needed to be taken into consideration before any decision was made on proceeding with the issue. The following describes the basic information[1] discussed at the meeting:

> DET/RES received two draft reports from Lawrence Livermore National Laboratory (LLNL) on the trial implementation of the Senior Seismic Hazard Analysis Committee (SSHAC) guidance for conducting a probabilistic seismic hazard assessment (PSHA). The SSHAC developed the guidance for conducting a PSHA based on lessons learned from the earlier results from LLNL and EPRI PSHAs. In 1998, RES undertook a project to conduct a trial implementation of the SSHAC guidance at two reactor plant sites in the southeastern United States: Vogtle and Watts Bar.
>
> The first draft report described the detailed application of the SSHAC guidance to the Vogtle and Watts Bar sites. Results from the first draft report for the two sites were compared to the seismic hazard estimates previously generated by EPRI and LLNL for Watts Bar and Vogtle. The PSHA results for the Vogtle site decreased slightly (within the uncertainty of the hazard estimate). In contrast, the PSHA results for the Watts Bar site showed that the mean annual frequency of exceeding the SSE design ground motion level of 0.18g slightly increased from about 0.0002 exceedances/year, based on the earlier LLNL results, to 0.0004 exceedances/year. Since this increase was unexpected, LLNL was requested to review the first draft report to determine the reasons for the change in the Watts Bar hazard estimate. The second draft report contained the results of this review.
>
> LLNL identified two sources for the increase in seismic hazard for the Watts Bar site. The first source is associated with using an updated model for the propagation of

earthquake ground motion in the eastern United States. The second source is a new composite seismicity model for the region. The seismicity experts used for the trial implementation of the SSHAC methodology identified and assigned high credibility to the ETSZ, which includes the Watts Bar site. Although the ETSZ has not produced a damaging earthquake in recent history (the largest recorded magnitude is 4.6), there has been an increase in the number of small earthquakes (magnitude 3) recorded by seismic stations in the ETSZ over the past 20 to 30 years.

DET/RES conducted a review of the results from the second draft report and plotted its findings which showed: (1) the Watts Bar design response spectrum anchored at 0.18g; (2) the IPEEE spectrum used for the Watts Bar study anchored at 0.30g; and (3) a uniform hazard spectrum calculated using the new hazard results at a mean return period of 10,000 years, which corresponds to a mean reference probability of 10^{-4} (See Figure 1). A comparison of the three spectra showed that the new hazard results were enveloped by: (1) the Watts Bar design response spectrum, below about 7 Hz; and (2) the IPEEE spectrum, below about 9 to 10 Hz. Since the natural frequency range for most structures and equipment in nuclear power plants falls below 10 Hz, it is expected that the new hazard results will have a minimal effect on major structures, systems, and components at Watts Bar. High frequency ground motion above 10 Hz generally affects only active components, such as contacts and relays, which are subject to chatter. Relays and components with high frequency sensitivity have been explicitly addressed in IPEEE evaluations.

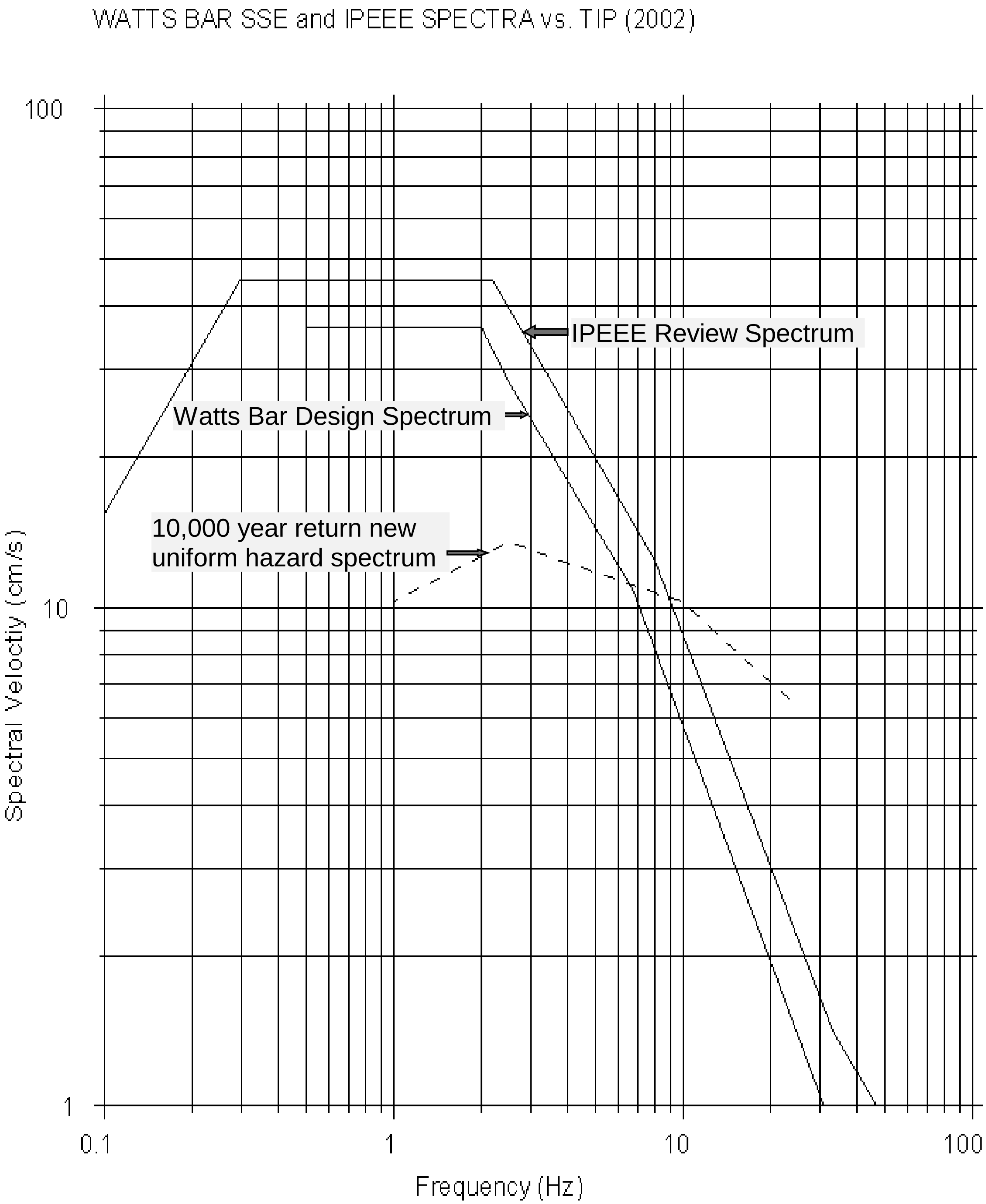
Conclusion

The panel discussed at length the basis for the IPEEE guidance on dealing with the high frequency issue and compared various ground motion spectra, including the latest models of NUREG/CR-6728[2] for the eastern United States. During the IPEEE guidance development, the issue of high frequency was explicitly addressed. As discussed above, the high frequency motion affects components, such as relays, and brittle components, e.g., potentially some anchorage. Based on tests conducted by NRC and the industry, a list of relays with known vulnerability was developed. During the IPEEE process, the plants were specifically addressing these relays. When identified, these relays were either replaced or shown not to have an adverse impact. The industry had also conducted tests to address the anchorage issue. Comparison of the ground motion results by NRC (NUREG-1488[3]) and EPRI,[4] and new results show differences in the ground motion level, but the frequency characteristics are essentially the same.

Attachment 2 contains approximate analyses of core damage frequencies (CDF) using the LLNL hazard curves (NUREG-1488) and the new hazard curves. These calculations are basically qualitative in nature as a number of simplifying assumptions were made. However, they are indicative of the fact that the new hazard curves do not show a major impact on the CDFs. Given the uncertainties in the seismic CDFs, a change of a factor of 2 is indicative of low sensitivity.

The panel was also shown a sample of preliminary results of an ongoing USGS seismic hazard study. When completed, results of this study should be evaluated to determine if there are significantly different frequency characteristics of ground motion than those used in the IPEEE evaluation.

FIGURE 1


WATTS BAR SSE and IPEEE SPECTRA vs. TIP (2002)
IPEEE Review Spectrum
Watts Bar Design Spectrum
10,000 year return new
uniform hazard spectrum
100
10
1
Spectral Velocity (cm/s)
0.1
1
10
100
Frequency (Hz)

Based on the above considerations and revised analysis in Attachment 2, the panel has concluded that the issue did not represent a new safety concern and recommended that the issue be dropped from further pursuit.

References

1. Memorandum to J. Zwolinski from M. Mayfield, “Review of Two Contractor Reports Associated with the Trial Implementation of the Senior Seismic Hazard Analysis Committee’s Guidance for Probabilistic Seismic Hazard Assessments,” May 29, 2002. [ML021580183]

2. NUREG/CR-6728, “Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-consistent Ground Motion Spectra Guidelines,” U.S. Nuclear Regulatory Commission, October 2001.

3. NUREG-1488, “Revised Livermore Seismic Hazard Estimates for 69 Nuclear Power Plant Sites East of the Rocky Mountains,” U.S. Nuclear Regulatory Commission, April 1994.

4. EPRI NP-6395-D, “Probabilistic Seismic Hazard Evaluation at Nuclear Plant Sites in the Central and Eastern United States: Resolution of the Charleston Issue,” Electric Power Research Institute, April 1989.

ANALYSIS OF GI-194, "IMPLICATIONS OF UPDATED PROBABILISTIC SEISMIC HAZARD ESTIMATES"

DESCRIPTION

A draft report on the trial implementation of the Senior Seismic Hazard Analysis Committee (SSHAC) guidance[4] for probabilistic seismic hazard assessment to Watts Bar and Vogtle[5] shows a higher probabilistic seismic hazard estimate for the Watts Bar site than the value obtained from NUREG-1488[3]. The increase in the seismic hazard estimate was investigated in a follow-on study and presented the root causes to be a combination of characteristics of the Watts Bar site, such as the site-specific source zones characterization, and more generic ones, such as the modified ground motion model. Other sites, depending on whether new information is available or not, could have similar conclusions, or not, such as in the case of Vogtle, for which the mean estimates of the seismic hazard slightly decreased between the Eastern United States (EUS) 1993 and the Trial Implementation Plan (TIP) 1998 studies. This represents a new interpretation of new seismicity data. The safety issue is: Does the new data warrant concerns regarding the seismic design bases for nuclear power plants in the region around the Eastern Tennessee Seismic Zone (ETSZ)? Also, are other nuclear power plants in the region adversely affected?

Historical Background

The U. S. Nuclear Regulatory Commission (NRC) has sponsored the development of a Probabilistic Seismic Hazard Analysis (PSHA) methodology through its contractor, the Lawrence Livermore National Laboratory (LLNL) since the early 1980's. For the purpose of conducting a systematic evaluation of the licensing criteria for older plants, a limited study[1] of the seismic hazard at the sites where these plants are located was conducted by LLNL in 1982. In a letter in 1982, the United States Geological Survey (USGS) suggested that deterministic and probabilistic evaluations of seismic hazard should be made for the EUS to assess the likelihood of large earthquakes along the eastern seaboard. This led to the PSHA study[2] of all 69 sites in the Central and Eastern United States (CEUS) by LLNL in 1988. In conjunction with funding the LLNL study of 1988, NRC also recommended that the nuclear power industry conduct an independent study to present a coordinated utility position on PSHA estimates. The industry study of 56 CEUS sites was conducted by the Electric Power Research Institute (EPRI). The EPRI results were published in EPRI-NP-4726 in 1986.

Large differences in the seismic hazard results between those from the LLNL study and the EPRI study led to the examination of the conflicting results. The staff decided to supplement the LLNL study by improving the elicitation of data and its associated uncertainty from the experts to better capture the uncertainty in our knowledge. The results of this study[3] were published in 1993.

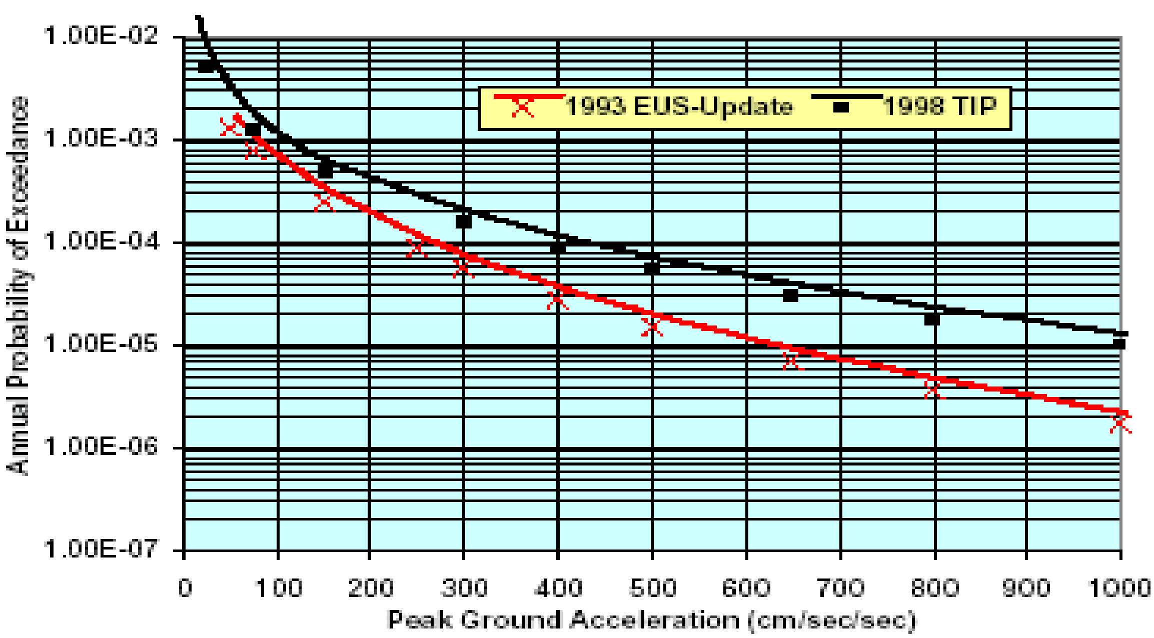
Although the PSHA results in Reference 3 show that there is reasonable agreement on plant-specific safe shutdown earthquakes (SSEs), the LLNL seismic hazard estimates in the 10^{-4} to 10^{-6} range are systematically higher than the EPRI hazard results for this range. This is the range of seismic hazard that typically has the most influence on the contribution to seismic risk for nuclear power plants. In an attempt to better understand the reasons for the differences in the two methods, the SSHAC was established under the sponsorship of NRC, EPRI, and the Department of Energy (DOE) in early 1993. The SSHAC published its report[4] in April, 1997.

The SSHAC report states, "Originally, some of the sponsors and participants proposed that one key objective should be to 'resolve' the differences between the Livermore and EPRI studies. However, the Committee quickly realized that the new project would be most useful if it were forward-looking rather than backward-looking - specifically, if it could pull together what is known about PSHA in order to recommend an improved methodology, rather than specifically attempting to figure out which of the two studies was 'correct,' or which specific problems with either study were most important in affecting the study's specific results."

In order to apply the SSHAC methodology, LLNL was sponsored to perform a study[5] (the TIP) of two trial sites, Watts Bar and Vogtle, in the Southeastern United States and the draft study was completed in 1998. The TIP results for the Watts Bar site indicated that at the mean annual frequency of 10^{-4}, the peak ground acceleration (PGA) value is about 0.45g, compared to a PGA of about 0.28g at the same mean annual frequency of 10^{-4} from Reference 3. In order to investigate the reasons for the difference in the results from the TIP and the earlier LLNL study, another study[6] was conducted, and a draft report was prepared in March, 2002. As discussed in the issue description above, the introduction of the ETSZ, and to a lesser extent the change in ground motion attenuation model, increased the potential for higher seismic hazard at sites in the proximity of the ETSZ.

Safety Significance

A comparison of the TIP and Reference 3 hazard curves for the peak ground acceleration values is shown in the plot shown below.



Comparison of the Mean Seismic Hazard Estimates for the Watts Bar Site

At the reference annual frequency of 10^{-4}, the TIP results are about 1.6 times higher than the 1993 EUS-Update estimate. Sites with operating plants in the proximity of the ETSZ are Browns Ferry, Sequoyah and Watts Bar. Based on the results for the Watts Bar site, there is a potential that the ETSZ could influence the seismic hazard at these other sites as well. The effect of changes in ground motion model, although secondary in nature, can increase the response spectrum shape in the high frequency range from 9 Hz to 50 Hz. A recent study[11] also shows the increase of spectral ordinates in the high frequency end. Seismic input in the high frequency end of the response spectrum can cause relay chatter and other effects to vibration-sensitive components. The USGS seismic hazard maps for the Eastern Tennessee area also indicate a higher seismic hazard.

Risk Implication

The assessment of seismic risk using seismic probabilistic risk assessment (PRA) models starts with a seismic hazard curve (e.g., frequency of exceedence versus PGA), as described above. Then, fragility curves (conditional frequency of failure versus PGA) for each structure, system, and component of interest must be derived. Finally, the fragility curves are convolved with the seismic hazard curve using event tree and/or fault tree logic models to calculate the frequency of various end states (e.g., core damage frequency) - a fairly involved numerical integration. This calculation can be rather formidable - much more so than the usual internal events PRA, since a seismic event can both initiate an accident and also serve as a common mode failure mechanism for many components, structures, and systems in the plant.

If the change in the seismic hazard curve were a constant multiplicative factor, constant over the domain of the curve, the resulting change in seismic core damage frequency (CDF) would also be a simple multiplicative factor, since the proportional change would carry through the entire calculation. However, the TIP curve does not differ from the original curve by a constant factor. This does not change the Boolean logic of a PRA, but does change the numerical integrations. Another complication is that many plants do not have a seismic PRA, but rather as part of their individual plant examination of external events (IPEEE), many licensees performed a seismic margins analysis (SMA). This results in no quantification of the seismic risk at these plants, though it does provide a determination that there are safe shutdown paths that meet a required review level earthquake (RLE) and also identifies any potential vulnerabilities associated with those paths. For these plants, the IPEEE typically does identify an overall plant high confidence of a low probability of failure (HCLPF) value, though this value may take credit for plant modifications to resolve the identified vulnerabilities, anomalies, outliers, etc.

Fortunately, a recent paper by Robert P. Kennedy[9] presents an approximate method of estimating seismic risk using the plant HCLPF value. This method assumes that the seismic hazard curve can be approximated by an exponential curve and that the fragility curves can be approximated as being lognormally distributed. Both assumptions are reasonable approximations for the purposes of the screening of this issue. Using these assumptions, this method develops a closed form solution for the seismic risk, which was developed for use in sensitivity studies such as this. This method was used to develop a sense of the change in the risk estimates, based on the different seismic hazard curves (i.e., LLNL 1993 versus TIP 1998) for the Watts Bar site. As a caution, these are simplistic calculations that give a "ballpark" estimate of the seismic CDF. However, a reasonable estimate of the expected change in CDF resulting from the change to the latest seismic hazard estimate can be obtained by applying the same approach to both sets of seismic hazard information.

The TIP results indicate that the mean seismic hazard estimate for Watts Bar is about two times greater than estimated in NUREG-1488. To compare the impact of this new seismic hazard information on CDF for Watts Bar, a simple calculation was carried out using the approximate method described above. The specific steps of the approach are identified in Section 6.2.1 of the Kennedy paper.

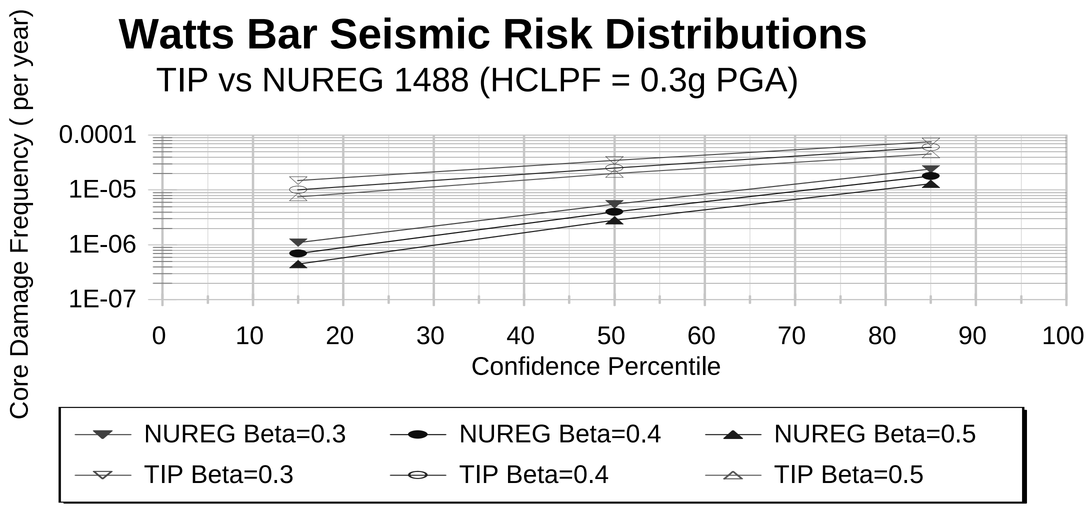
This calculation addresses only the seismic contribution. It does not address random equipment failures/unavailabilities or operator errors. However, it is noted from the NRC contractor's technical evaluation report (TER) on the Watts Bar IPEEE submittal that "... non-seismic failures are not expected to be significant for WBN [Watts Bar Nuclear] because there seems to be sufficient diversity and redundancy in the equipment selected in the SSEL [safe shutdown equipment list] for the success paths ..." and that "... significant human action problems are not expected for WBN." Therefore, neglecting any contribution to the core damage frequency from simultaneous random equipment failure or adverse human action in this simple calculation, should not lead to erroneous results.

The Watts Bar IPEEE seismic analysis was performed in accordance with the EPRI SMA methodology as described in EPRI NP-6041-SL.[10] Their results indicated that the plant HCLPF value exceeded the RLE of 0.3g PGA. There were no significant issues identified in the staff's safety evaluation report (SER) or contractor's TER on this analysis and there were no identified seismic vulnerabilities, anomalies, outliers, etc.

The simple calculation includes some assumptions regarding the plant's seismic capability. For this calculation, the logarithmic standard deviation of 0.4 that is recommended in the Kennedy paper is used. A lower logarithmic standard deviation would result in higher calculated CDF and change in CDF values. In addition, Watts Bar has identified two success paths that both exceed a HCLPF value of 0.3g PGA. Using the HCLPF Max/Min method rules, the plant HCLPF is equal to the greater of the HCLPF values for these two success paths. However, it is not clear from the SER or TER what precise HCLPF values were achieved for each success path; only that they both exceeded 0.3g PGA. Therefore, in this analysis both success paths are assumed to only just meet the 0.3g PGA and thus, this capacity is also used to represent the plant HCLPF in the analysis. If a higher HCLPF value were used, lower CDF and change in CDF values would be calculated. With the plant HCLPF of 0.3g PGA and assuming the logarithmic standard deviation of 0.4, the simplistic approach can be used to estimate the risk associated with seismic events for the different seismic hazard information.

Using this method and the LLNL seismic hazard information documented in NUREG-1488, the Watts Bar seismic CDF is estimated to be about 1×10^{-5} per reactor-year. Using this approach and the new seismic hazard information from TIP, the Watts Bar seismic CDF estimate increases to about 4×10^{-5} per reactor-year. This approach implicitly assumes no change in the spectrum shape from the IPEEE study. But the TIP uniform hazard spectrum, which is based on 10^{-4} mean pga value, has higher spectral acceleration values than the design SSE spectral acceleration values above about 7 Hz and the increase peaks at about 25 Hz. However, in the 1 to 7 Hz range, the spectral acceleration values are significantly below those from the SSE spectrum. In order to account for the effect of this difference in spectrum shape on the core damage frequency (CDF), the Watts Bar plant HCLPF value, 0.3g, was scaled to the spectral acceleration values at 5 and 10 Hz, and the scaling relationships for 5 and 10 Hz spectral ordinate from the TIP uniform hazard spectrum were used to determine the CDF values at 5 and 10 Hz. The resulting averaged CDF is 1.8×10^{-5} per year. Therefore, accounting for the TIP uniform hazard spectrum shape, there is an increase in CDF of about 0.8×10^{-5} per year.

In order to determine the sensitivity of the estimated CDF for the Watts Bar site using the TIP seismic hazard curve, several CDF estimates were made using the mean, 15th, and 85th percentile hazards, with varying uncertainties (beta values).



From the above figure, it is apparent that the CDF values are not very sensitive to the percentile level of the hazard curve. This is because the HCLPF value is high and at the low end of the annual frequency of occurrence.

OTHER RELATED STUDIES

This GSI is specifically concerned about plants in the Eastern Tennessee Seismic Zone. However, the USGS has undertaken a nation-wide effort of seismic hazard mapping under the National Earthquake Hazard Reduction Act. In early 2003, USGS issued revised hazard maps using a methodology quite similar to the SHAAC approach. RES is currently conducting a study of the USGS methodology as a part of the ten-year seismic data base updating activity. This project will lead to an assessment of seismic hazard at existing plant sites. At the end of the RES study, a comprehensive perspective of the increase or decrease of plant seismic hazard and its effects on the SSE ground motion at all the EUS plants will be available.

CONCLUSION

At this time, based on the spectrum shape based risk estimates for the WBN site, and using Figure C5 in Management Directive 6.4, this issue regarding the adequacy of deterministic seismic design criteria for the licensing basis of plants in the ETSZ can be excluded from further consideration. If the revised USGS results confirm the TIP results and show increases in the seismic hazard for more sites, a generic study may be required to assess the significance for other plants.

REFERENCES

(1) NUREG/CR-1582, “Seismic Hazard Analysis,” April, 1983.

(2) NUREG/CR-5250, “Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains,” January, 1989.

(3) NUREG-1488, “Revised Livermore Seismic Hazard Estimates for 69 Sites East of the Rocky Mountains,” October, 1993.

(4) NUREG/CR-6372, “Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts,” April, 1997.

(5) NUREG/CR-6607, “Guidance for Performing Probabilistic Seismic Hazard Analysis for a Nuclear Plant Site: Example Application to the Southeastern United States,” August 18, 1998.

(6) UCRL-ID 142039, “Comparison of the PSHA Results of the 1993-EUS-Update and the 1998-TIP Studies for Watts Bar,” March, 2002.

(7) NUREG-1407, “Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities,” June, 1991.

(8) NUREG-1742, “Perspectives Gained From the Individual Plant Examination of External Events (IPEEE) Program,” April, 2001.

(9) Kennedy, R.P., “Overview of Methods for Seismic PRA and Margin Analysis Including Recent Innovations,” Proceedings of the OECD-NEA Workshop on Seismic Risk, Tokyo, Japan, August 1999. Available from OECD Nuclear Energy Agency, La Seine St.-Germaine, 12 Boulevard des Iles, F-92130 Issy-les-Moulineau, France.

(10) EPRI-NP-6041-SL, R1, Nuclear Power Plant Seismic Margin, Revision 1, August 1991.

(11) NUREG/CR-6281, “Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard and Risk-consistent Ground Motion Spectra Guidelines,” October 2001.

Approximate CDF Calculation for
Watts Bar Site Seismic Hazard Curve
Based on SHAAC Methodology

Use the following assumptions and attributes:

1. Trial Implementation Plan (TIP) seismic hazard curve for pga
2. TIP uniform hazard spectrum shape for 10^{-4} per year mean peak ground acceleration value is 0.45g.
3. 5% damped spectrum curve
4. Plant HCLPF value from IPEEE is at least 0.3g pga
5. Ratio of 5 Hz spectral acceleration, S_A to pga is 2.12 for IPEEE
6. Ratio of 10 Hz spectral acceleration, S_A to pga is 1.86 for IPEEE
7. Beta factor of 0.4, results in ratio of 10% value to mean value of about 1.5
8. Robert Kennedy's simplified method

Based on IPEEE information:

5 Hz spectral acceleration at HCLPF = 0.3 x 2.12 = 0.64g
10 Hz spectral acceleration at HCLPF = 0.3 x 1.86 = 0.56g

Corresponding 10% value for S_A at 5 Hz is 1.5 x .64 = 0.96g and at 10 Hz is 1.5 x .56 = 0.84g

TIP results:

5 Hz spectral acceleration value = 12.5 x 2 x π x 5/900.665 = 0.4g
10 Hz spectral acceleration value = 10.5 x 2 x π x 10/900.665 = 0.67g
Ratio of 5 Hz spectral acceleration, S_A to pga is 0.4/0.45 = 0.89
Ratio of 10 Hz spectral acceleration, S_A to pga is 0.67/0.45 = 1.49

At 5 Hz, 10% value for S_A is 0.96g/0.89 = 1.08g
At 10 Hz, 10% value for S_A is 0.84g/1.49 = 0.56g

From TIP hazard curve, probability of exceedance (POE) for 5 Hz S_A of 1.08g is 1.3 x 10^{-5} per year, CDF = 1.3 x 10^{-5}/2 = 0.65 x 10^{-5} per year.
POE for 10 Hz S_A of 0.56g is 6 x 10^{-5} per year, CDF = 6 x 10^{-5} /2 = 3 x 10^{-5} per year.

Average CDF using TIP hazard curve and uniform hazard spectrum is 1.8X10^{-5} per year.