A PROBABILISTIC MODEL FOR SEISMIC ANALYSIS OF NUCLEAR PLANT STRUCTURES

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SUMMARY

The influence of the variation of structural parameters on its seismic response has been of concern to engineers in power plant design. This is especially true for cases where the response of the primary structure is used as an input to analyze piping, equipment and other secondary systems. Presently it is a common practice to assume conservative values of seismic input and structural design parameters to evaluate the structural response. In case of the floor response spectra, the peak responses are widened to account for possible variation in structural frequencies. Studies have shown that this procedure, at times, leads to an unduly conservative response for a certain range of frequencies and may possibly lead to an unconservative response in another range. To quantify the degree of conservatism, a probabilistic approach is adopted.

In this paper a probabilistic seismic model is developed using the modal method of analysis. A Gaussian probability distribution for the mass, Young's modulus, member dimensions and damping is assumed. The mean and standard deviation of these quantities are determined from published data. Based on these properties the mean and standard deviation of the mode shapes and frequencies of the structure is established. The procedure assumes linear perturbations of the eigenvalues and eigenvectors and only requires the solution of a single eigenvalue problem. It is shown that the error because of the linear approximation is generally less than one percent for the range of variation expected in nuclear power plant structures. Based on the mean and standard deviation of the structural mode shapes and frequencies the statistics of the various structural responses are established using the Monte Carlo technique. For a typical power plant structure responses are obtained by the present deterministic approach using the mean values of the structural mass and stiffness, mean plus one sigma value of input excitation and the mean minus one sigma value for the structural damping. These responses are compared against the response statistics obtained from the probabilistic model to compute the probability of exceedance. It is shown that present methods yield conservative responses with only a two to ten percent probability of exceedance.

The influence of the variation of the structural properties on the floor response spectra is also evaluated. In the deterministic case the mean values of the structural mass and stiffness, mean plus one sigma value of the input excitation and the mean minus one sigma value of structural damping is used. The peaks of the spectra obtained are widened by plus and minus ten percent as is required in the present practice. This spectra is compared to a mean plus one sigma spectra obtained from the probabilistic model. It is shown that the present method overestimates the spectra peaks by twenty to fifty percent; however for frequencies away from the resonance zone the present responses are comparable to the mean plus one sigma spectra.