A DISCUSSION OF COUPLING AND RESONANCE EFFECTS FOR INTEGRATED SYSTEMS

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SUMMARY

It is customary to conduct seismic analysis of a nuclear power plant by dividing systems according to design responsibilities and systems design classifications. To account for the possible interaction effects between the systems, many analysts have adopted the approach of either taking into account the stiffness or the weight of the interacting systems which are not considered an integral part of the model.

In this paper, three representative cases have been studied to evaluate the interaction effect and to establish the need to include both stiffness and mass of the interacting systems in the system model. The first case is a supported system supported by a two degree of freedom supporting system. The second case represents two single degrees of freedom systems each supported by itself but interconnected by a spring. The third case represents a single degree of freedom supported by another single degree of freedom supporting system.

In each of the three cases studied, the interaction effect is first measured by the errors incurred in the natural frequencies, for both the supported systems and the supporting systems. Several important conclusions can be drawn from the results. These are:

1. While the stiffness approach provides more accurate natural frequencies for flexible supported systems, the mass approach is more accurate for rigid supported systems. However, both approaches fair poorly as compared with the approach which includes neither the mass nor the stiffness, for overall performances when the rigidity of the supported systems is uncertain.
2. Errors appear to be consistently greater for the supported systems than the supporting systems.
3. Largest errors for case two occur when the support stiffness of the supported system is zero. Which, in fact, reduces to the model of case three.
4. Errors in all cases studied are highest when both systems are in resonance and greater when the mass ratio of the supported system to the supporting system is larger.

Although natural frequencies are important to the dynamic analysis of a system, the ultimate decision of whether the mathematical model is realistic depends on the results of the system response it predicts. With this in mind, and also taking into account the conclusions reached in the earlier discussions, case three is then studied with a white noise spectral density input. It is found that the mean square response of both the supported and supporting systems are substantially lower when coupled than when the systems are analyzed separately. Consequently, interaction represents an important factor for reducing the design loads. When both systems are in resonance, the fractional reduction in the mean square response of the supported subsystems can be predicted by the following formula:

$$\frac{(1+3\mu)\,\xi_1\,\xi_2}{\xi_1\,\xi_2+\mu/4}$$

where ξ_1 and ξ_2 are damping ratios for the supporting and supported systems, respectively, and μ is the mass ratio of the supported system to the supporting system.