Final Project Summary — PEER Lifelines Program

Project Title—**ID Number**	*Input Motions for Earthquake Simulator Testing of Electric Substation Equipment*—**408**		
Start/End Dates	5/1/00 – 9/30/01	Budget/ Funding Source	$40,000/ PG&E/CEC
Project Leader (boldface) and Other Team Members	**Anderson (UNR)**		

1. Project goals and objectives

Improving the specifications for input motions for earthquake simulator testing of electric substation equipment.

2. Benefits of the results of this project to develop technologies and protocols to mitigate the vulnerability of electric systems and other lifelines to damage directly and indirectly caused by earthquakes. Also, benefits to develop assessment techniques to evaluate damage to electric systems caused by earthquakes and to assess fiscal impacts due to the loss of electric service to the community.

(1). The spectral matching method we developed provides a useful technique to scale historical earthquake records for use in engineering testing or designing. **(2).** Our results by examine ground motion response spectra from recent large earthquakes indicate the shape of the seismic response spectra show strong magnitude dependence. That dependence is useful for some earthquake resistant design situations. The IEEE-693 spectrum is exceeded by the average spectra at long periods for sites in the softest category, as a result of soil amplification. However, the magnitude dependence of the spectrum will cause the low frequencies to be amplified relative to the high frequencies for larger earthquakes. The result is that it will be no surprise to see the low frequency part of the spectrum exceeding the IEEE spectrum for all site categories in a significantly larger magnitude earthquake.

3. Brief description of the accomplishments of the project

In this project, we have accomplished two major tasks. **(1).** we have developed a method to calculate accelerograms that match a testing or designing target spectrum for appropriate earthquake magnitude, distance, and site conditions. Adjustments are made to acceleration-time history records by computing the response spectra and determining the amount of adjustment needed in different period ranges to nearly match the target spectrum. Fourier spectra are then computed. The Fourier amplitude spectra are adjusted while the Fourier phase spectra are preserved. The inverse Fourier transform is used to re-compute acceleration-time histories. If necessary, the procedure can be iterated to achieve reasonably optimal spectral matching. **(2).** we have examined ground motion response spectra from the recent large earthquakes in California, Japan, Turkey and Taiwan. We have studied the distance, site, and magnitude effect on the shape of the response spectra and compared these response spectra with the standard response spectra specified by the IEEE 693-1997 for high seismic performance level. We found the shape of the response spectra show strong magnitude and site dependency, but weak distance dependency. A larger earthquake generates much more long-period seismic energy than a smaller earthquake. An average soft soil site shows higher amplification of the long-period seismic signal than a rock or stiff soil site. Thus, the normalized spectra from a large earthquake recorded on a soft soil site have the highest likelihood of exceeding IEEE 693-1997 at long periods. By comparing acceleration response spectra with the response spectrum given in IEEE 693-1997 for high seismic performance level, we found the stations that exceed the absolute level of IEEE 693-1997 response spectrum are generally located: 1) very close to the fault rupture trace; 2) near the edge of a fault in a location that experienced a strong directivity effect; 3) on the hanging wall adjacent to the primary fault trace; or 4) at a site that experiences large site amplification. In the low frequency range, the excedance is usually associated with a larger magnitude earthquake at soft soil sites at near source distance (D<50 km). For larger earthquakes, exceedance at low frequencies may become more common.

4. Describe any instances where you are aware that your results have been used in industry

Spectral match method is been used.

5. Methodology employed

We have used Fast Fourier Transforms (FFT), inverse FFT and standard spectral analysis methods.

6. Other related work conducted within and/or outside PEER

We have also studied nonlinear site response effect on response spectra, explored the effects from distance, magnitude and site response on response spectra and compare them with building codes.

7. Recommendations for the future work: what do you think should be done next?

Analysis the results we have obtained as well as other related work and develop recommendations to future IEEE standards.

8. Author(s), Title, and Date for the final report for this project

Title of the final report: Input Motions for Earthquake Simulator Testing of Electric Substation Equipment (408), by Feng Su, Yuehua, John G. Anderson, August, 2002.