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 – 6/30/04	Budget/ Funding Source	$90,720 / PG&E/CEC
Project Leader (boldface) and Other Team Members	**Fenves (UCB)**		

1. Project goals and objectives

The main objective of the study was to develop a set of earthquake ground strong motion time histories suitable for seismic qualification testing of electrical substation equipment in accordance with the IEEE 693-1997 standard. Although the study's objective deals with shake table testing of a particular class of equipment, many of the issues investigated are equally relevant to the dynamic testing of other types of equipment and components. This study was motivated by a desire to introduce a standard set of input motions in three orthogonal directions, and thus achieve more consistency in earthquake simulator testing. The project is focused on developing an input strong motion based on a record of actual earthquake with a time-domain spectral matching procedure, so the spectrum-compatible strong motion time history would preserve the non-stationary behavior of the real record. Figure 1 shows the elastic response spectra of the proposed strong motion time history (TestQke4IEEE) for qualification testing of electrical equipment closely matching the IEEE 693 required response spectra.

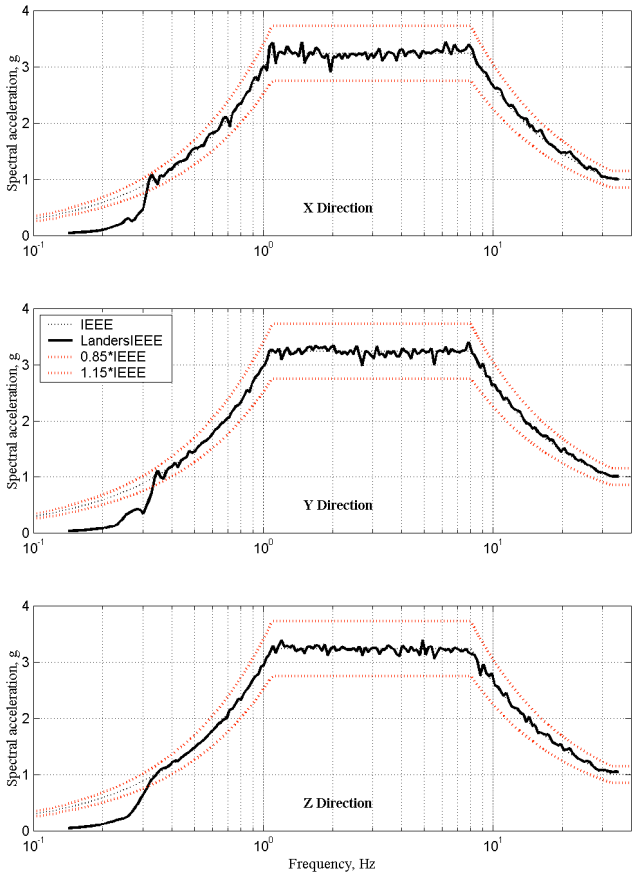

Fig. 1 IEEE-compatible Landers (TestQke4IEEE) at 2% damping (1/24 octave resolution).

A selection of 35 three-component historic records from 18 earthquakes was analyzed and the records were cross-compared based on use several parameters. From the analysis the best candidate for the input strong motion was selected and modified by adding non-stationary wavelets to the signal. The resulting strong motion time history

preserves the non-stationary behavior of the real earthquake record while its response spectra envelope the IEEE target response spectra in a broad range of natural frequencies as required by the standard. The resulting strong motion time history is intended for use by testing facilities, and will be considered for inclusion in a future revision to IEEE 693.

Additional requirements on the input motion generation and the IEEE seismic qualification procedure are recommended. The requirements are proposed for inclusion in the new version of the IEEE 693 standard.

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.

The project deliverables benefit the industry by providing newly developed requirements and a strong motion time history for seismic qualification testing of electrical equipment in accordance with IEEE 693.

3. Brief description of the accomplishments of the project

The main objective of the study was achieved and a three-component set of earthquake ground motion time histories suitable for seismic qualification of electrical substation equipment in accordance with the IEEE 693-1997 standard (IEEE, 1998) was developed. The strong motion time histories in three principal directions of testing are available for download from the Westcoast Subcommittee's web site:
http://www.westcoastsubcommittee.com/ieee693/qualified.php.

Along with the set of strong motion time histories, the study provides specifications for spectral matching procedure and extended requirements on the IEEE-compatible time history. The recommendations on requirements for test response spectrum (TRS) are also provided. The specifications and requirements are summarized in 'Specification for Input Motion Used in Earthquake Simulator Testing Under IEEE 693' in Appendix C of the project's report and is available on the PEER's web-site:
http://peer.berkeley.edu/lifelines/Task408_411/Task408.html.

Matlab (The MathWorks, 2001) codes developed in the study form another set of the study's deliverables. The set consists of implementations of the filtering procedure and of the high cycle counting procedure in single degree of freedom system response. The codes are available at the Westcoast Subcommittee's web site provided above.

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

The test strong motion time history (TestQke4IEEE) was used during a companion experimental study on seismic qualification of a 500-kV disconnect switch: Shakhzod M. Takhirov, Gregory L. Fenves, Eric Fujisaki. 'Seismic Qualification and Fragility Testing of Line Break 550 kV Disconnect Switches'. The newly developed requirements on the time history testing procedure have been included in the current draft version of the IEEE 693 document.

5. Methodology employed

The scope of the work was achieved by means of a comprehensive theoretical study and some experimental study on an earthquake simulator performance with no specimen attached.

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

Shakhzod M. Takhirov, Gregory L. Fenves, Eric Fujisaki. 'Seismic Qualification and Fragility Testing of Line Break 550 kV Disconnect Switches'.

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

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

Shakhzod M. Takhirov, Gregory L. Fenves, Eric Fujisaki, Don Clyde. 'Ground Motions for Earthquake Simulator Qualification of Electrical Substation Equipment'. 06/30/2004.