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Input Motion for Earthquake Simulator Qualification of Electrical Substation Equipment

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Overview

The objective of the study was to develop a set of earthquake ground strong motions as input to shake table for seismic qualification testing of electrical substation equipment in accordance with the IEEE 693-1997 standard. The motivation was to develop a standard set of input motions to achieve more consistency in earthquake simulator testing.

Thirty five three-component ground motions recorded in 18 earthquakes were analyzed and the records were cross-compared based on several parameters. The "best candidate" for the input motion was selected and modified by time-domain spectral matching procedure. 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 for equipment qualification testing, and will be considered for inclusion in a future revision to IEEE 693. Additional requirements for the input motion specification and generation procedure in the IEEE 693-1997 are recommended.

The strong motion time history developed was successfully used for a qualification test of a 500 kV disconnect switch on the shake table facilities at the Earthquake Engineering Research Center, the University of California, Berkeley.

Time History Generation for Testing

The study concluded that the 1992 Landers, California, recorded at the Joshua Tree station represents a robust strong motion time history (see reference 1 for details). The record was modified to match closely the IEEE 693 spectra at 2% critical damping by adding non-stationary wavelets to the record. The IEEE spectrum compatible strong motion time history is recommended for seismic qualification testing of electrical equipment in accordance with the IEEE 693 standard. The main advantages of the modified record are as follows.

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(1) The spectra of the strong motion time history fits inside a ±10% tolerance zone around the target IEEE response spectrum (at 2% damping) at a 1/24 octave frequency resolution, as shown in Fig. 1.

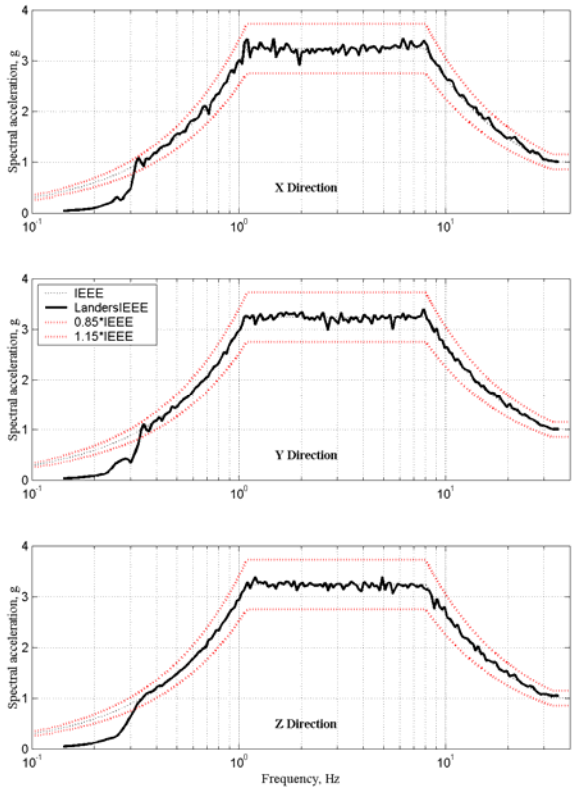

Fig. 1 - The IEEE-compatible Landers 3-component time history closely match the IEEE PL spectrum at 2% damping.

(2) The motion satisfies the 20 sec duration requirement of the IEEE 693 standard.

(3) The IEEE-compatible Landers represents a broadband record consisting of oscillations with frequencies from the wide frequency range specified by the standard.

(4) The non-stationary random behavior of the reference record is preserved during the target spectrum matching procedure carried out in the time domain.

(5) Among all the ground motion records studied, the IEEE-compatible Landers record has the highest ratio of the strong portion duration to the total duration.

(6) The cumulative energy of the IEEE-compatible Landers record is very close to that of CERL, the synthetic test time history examined in this study (see Reference 2).

(7) The number of high-level cycles in the single-degree-of-freedom system response under the impact of the IEEE-compatible Landers correlates well with the mean for the 35 records.

Availability of the Generated Records

The three components of the generated strong motion time history ("TestQke4IEEE" file) are available for download from the IEEE-693 West coast Subcommittee's website:

http://www.westcoastsubcommittee.com/ieee693/spectra/spectrums.htm (or it can be requested at 693-th@ieee.org). It is being considered for inclusion in a future revision to IEEE 693.

Example of Using the Generated Records

The strong motion time history developed was successfully used for a qualification test of a 500 kV disconnect switch on the shake table at the Earthquake Engineering Research Center, at the University of California, Berkeley (see reference 2 for details).

The switch was tested in two major configurations: (a) with the main contact closed, as shown in Fig. 2a; and (b) contact open, as shown in Fig. 2b. Due to the limited clearance above the earthquake simulator platform, the switch with the open contact was tested without 14' tall steel supports, commonly used by the utilities. In this case, the input motion was amplified to simulate the effect of the elevated mounting of the switch.

(a) **(b)**

Fig. 2 - Two major configurations of the 500 kV switch tested at the University of California, Berkeley

The switch was tested up to the PL seismic qualification level and it performed well without major failure up to this level. After the seismic qualification testing, the static fragility tests of the porcelain insulator posts were performed to estimate cantilever strength of the posts, as shown in Fig. 3.

Before failure At failure

Fig. 3- Static cantilever strength testing of the porcelain insulator posts

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Keywords

Seismic qualification test, IEEE 693 spectra, 500 kV disconnect switch, porcelain insulator post, earthquake simulator testing, spectral matching in time domain.