Effect of Dynamic Interaction in Interconnected Electrical Substation Equipment

J. Song[1], A. Der Kiureghian[2] and J. L. Sackman[3]

Overview

The conventional practice in the power industry for qualifying electrical substation equipment for seismic effects has been to individually test equipment items on a shake table for a specified base motion. This kind of testing, however, does not account for the effect of dynamic interaction that occurs in the field when the equipment is connected to other substation equipment through rigid or flexible conductors for power delivery and transformation. It is believed that this interaction effect is responsible for a large number of electrical substation equipment failures during recent earthquakes. The objective of this study was to investigate this effect and to develop analytical models for its quantification. This digest summarizes the main findings of the study for equipment items connected by rigid bus.

Connection Types

A rigid bus (or conductor) consists of an aluminum pipe and a flexible connector, which is installed at one end of the pipe for thermal expansion as well as to provide flexibility in the axial direction of the pipe. Figure 1 shows the five different connectors investigated as a part of this study. The first three are in current use, the fourth (*S*-FSC) is a new design developed as a part of the current study, and the fifth (Slider Connector, SC) is a new design under consideration by PG&E.

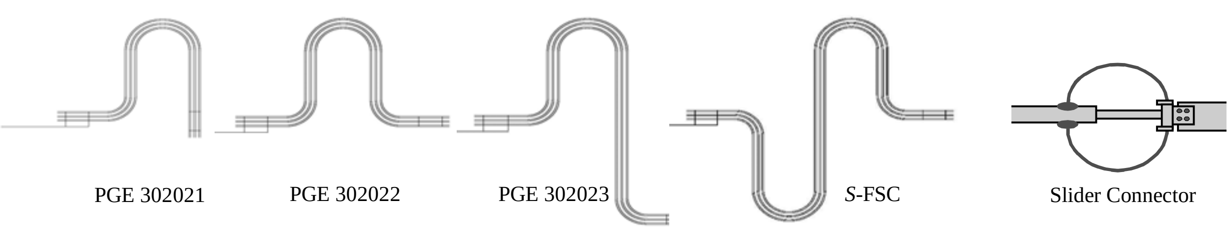

Figure 1 - Five flexible connectors investigated in this study

[1] Assistant Professor, Department of Civil & Environmental Engineering, University of Illinois at Urbana-Champaign.
[2] Taisei Professor of Civil Engineering, University of California, Berkeley.
[3] Professor Emeritus of Engineering Mechanics, University of California, Berkeley.

For each connector, an analytical mechanical model was developed to match its behavior under cyclic loads, as exhibited in tests conducted at University of California, San Diego. Figure 2 shows comparisons of the analytical and experimental hysteresis loops for the connectors PGE-302022 and *S*-FSC. It is seen that the analytical models closely match the experimental results, including the asymmetric behavior of PGE-302022. Furthermore, the *S*-FSC remains virtually elastic, thus not requiring retooling after an earthquake.

Dynamic Interaction

Assemblies of two equipment items connected by a rigid bus and each of the five flexible connectors were investigated to determine the dynamic interaction effect. A stochastic model of the ground motion and random vibration analysis by equivalent linearization method were used.

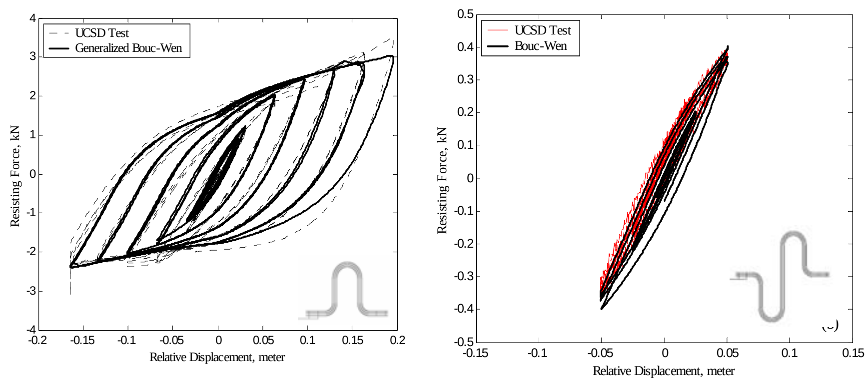

Figure 2 - Comparison of experimental and analytical hysteresis loops

Major findings from a comprehensive parametric study are reported in Song *et al*. (2005) and include:

1. Dynamic interaction may strongly influence the seismic demand placed on interconnected electrical substation equipment. In general, the seismic demand on the equipment item that has a higher frequency is amplified. The magnitude of the amplification depends on the frequency and mass characteristics of the equipment items, as well as the type of the connector, and can reach as high as 5 or even higher.

2. The *S*-FSC and SC sharply reduce the adverse effect of interaction on the high-frequency equipment item. Figure 3 compares the amplification factors on a 100 kg, 5-Hz equipment item that is connected to a 1 Hz equipment item having 100 kg or 500 kg mass. The results are shown as functions of the ground motion intensity. For

low intensity motions, the slider is locked due to friction, thus allowing strong interaction.

However, with increasing intensity, the slider overcomes friction and becomes flexible. The results in Figure 3 clearly demonstrate the advantages of the *S*-FSC and SC. The S-FSC has the added advantage of being much cheaper to manufacture than the SC, and not requiring retooling after an earthquake.

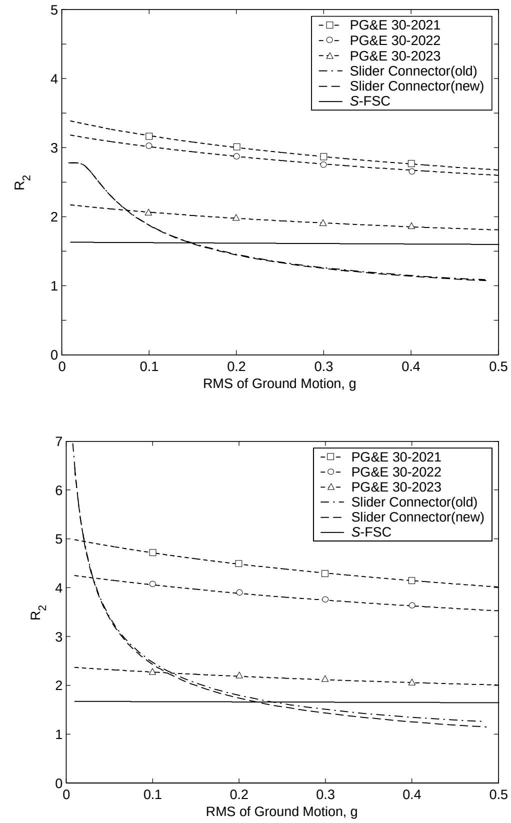

Figure 3 - Demand amplification on higher-frequency equipment item

Reference

Song, J., A. Der Kiureghian and J. L. Sackman (2005). Seismic response and reliability of electrical substation equipment and systems. *Report*, Pacific Earthquake Engineering Research Center, University of California, Berkeley.