ELECTRIC GRID RESEARCH

Project Summary

Analysis of Seismic Performance of Transformer Bushings

Context

Earthquakes are a significant threat to the integrity of the California electric transmission system. Much of the California electric system is in highly active seismic regions, including most of the large urban areas. Consequently, both the probability and consequence of earthquake damage to electric service reliability, infrastructure security and cost control are extraordinarily high. Post-earthquake functioning of utility systems is a vital need for rapid response, recovery, and preservation of public safety.

Previous research studies have resulted in significant knowledge of electric system seismic behavior and have led to substantial improvements in key areas. They have also identified remaining vulnerabilities and research that can lead to a more reliable, robust and resilient system. One of these areas is the bushing assembly in large substation transformers. These bushings are vulnerable to excessive vibrations caused by earthquakes. When such components fail or their oil content catches fire in the aftermath of an earthquake, there is a danger that the entire grid might be affected.

Experience from both laboratory testing and damage resulting from earthquakes indicates that the seismic qualifying procedures in the IEEE Standard 693 that are designed to assure adequate performance during earthquakes are not, in fact, producing the desired results. In particular, the procedure does not properly account for the interactions between the bushing mountings and the transformer housings, resulting in bushings that were successfully qualified to the Standard but failing in service.

Goals and Objectives

The goal of this research is to develop a revised IEEE Standard 693 for qualification of transformer bushings. It will provide manufacturers with the information they need to build bushings with predictable performance, and hopefully greater survivability in seismic events, thus preventing power interruptions.

The development requires highly complex modeling, and use of the most advanced seismic simulators available at the Structural Engineering and Earthquake Simulation Lab. The intent is to develop simplified procedures of analysis and testing, which can be used with confidence by less sophisticated laboratories and engineering organizations.

Description

This project will develop experimental techniques to determine the seismic stress capacity of bushings and, using advanced finite element modeling, will derive mechanical models to accurately simulate seismic response. The research will also define simplified procedures to incorporate the significant interactions among the assemblies and the structure of the entire transformer. The resulting development will be submitted to the IEEE 693 standards committee for adoption.

An initial workshop will be held with manufacturers, utilities and other researchers to identify the research parameters.

Four full scale bushings will be tested on the seismic simulator using current and proposed standards. Finite element models of several significant assemblies will be analyzed and compared with simplified mechanical models. Then, integrated procedures for qualification and design will be developed. The numerical models will use finite elements and the simplified models a series of nonlinear springs representing the components of the assemblies.

An advisory team from the power utility companies, bushing and transformer manufacturers, and commercial modelers and engineers, in cooperation with members of the IEEE 693 committee, will ensure development of a usable recommendation for new standards.

Why It Matters

Transformers are key elements in the electric transmission system, and the bushings that are bolted onto a transformer are one of the pieces of electrical equipment most vulnerable to seismic damage. In the event of a significant earthquake, failure of a bushing takes the transformer out of service, causing a severe disruption of electric service. Acquiring and installing a replacement bushing is an expensive and labor-intensive task, and one that can significantly delay recovery of power after a disruption. Laboratory testing and past failures during seismic events have made it clear that current standards are inadequate: manufacturers are building bushings that successfully qualify according to the Standard, yet are known to fail in service at lower seismic levels than they were tested to. Clearly, the Standard is not taking into account all the factors that cause bushings to fail during earthquakes. More effective standards, based on a combination of test data and simulation results, will provide the guidance for manufacturers to design more robust seismic performance into their bushings, will reduce the likelihood of bushing and transformer failures, and will thereby speed the recovery response to major earthquakes.

{More details}

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Participating Organizations

Principal Investigators:

Research Foundation and Multidisciplinary Center for Earthquake Engineering Research at State University of New York, Buffalo

Research Advisers:

Pacific Gas & Electric Co., Geosciences Dept.

Pacific Gas & Electric Co., Civil & Mechanical Engineering Dept.

San Diego Gas & Electric Co., Civil & Mechanical Engineering Dept.

Southern California Edison Co.

Western Area Power Administration

Precision Measurements International

Project Start Date: October 1, 2008

Project End Date: September 30, 2010

CIEE Contract No.: TRP-08-03

CEC Contract No.: 500-07-037

Reports

Final Report: *Analysis of the Seismic Performance of Transformer Bushings* (Not yet available)

Funding

Funds for this project came from a $241,430 award by the CIEE under a research contract 500-07-037 awarded to CIEE by the California Energy Commission (CEC) through the Public Interest Energy Research program (PIER)

For More Information, Contact

Dr. Merwin Brown,
CIEE Electric Grid Research Program Director
(916) 551-1871
merwin.brown@uc-ciee.org