ELECTRIC GRID RESEARCH

Project Summary

Analysis of the Seismic Performance of Substation Post Insulators

Context

Much of the California electric system is in highly active seismic regions, including most of the large urban areas. Post-earthquake functioning of utility systems is viewed by emergency responders and society in general as an absolutely vital need for rapid response, recovery and preservation of public health and safety. Building an electric system that is more resistant to seismic motion damage will reduce the consequences and costs of electric service disruptions caused by strong ground motions.

Porcelain insulators have been the most prevalent type of insulator used in electric substations. IEEE Standard 693 defines the acceptable strength capacity of an insulator as a fraction of its ultimate strength when subjected to earthquake loading, but does not provide sufficient guidance on how ultimate strength should be established. The current requirements for composite insulators (e.g., non-porcelain designs such as silicone rubber over fiberglass rod) need improvement when qualification by test is required. Recent tests performed by the Electric Utility Consortium (EUC), a collaborative effort under the direction of the Electric Power Research Institute (EPRI), have indicated that numerous hollow-core composite insulators failed or did not perform in a manner that was expected, even though they were qualified as per IEEE 693.

Goals and Objectives

The goals of this project are:

- To obtain better knowledge of the performance and potential failure modes of substation insulators, both porcelain (ceramic) and composite (non-ceramic) types, during seismic events.
- To develop revised qualification procedures into the IEEE 693 Standard for insulators specifying the performance requirements of these important transmission system components

Description

The research will include several tasks related to both porcelain and composite insulators. One is to measure the ultimate strength of porcelain substation post insulators as related to the seismic qualification standards of equipment. This will augment the already existing data from “traditional” cyclic testing of ceramic insulators, i.e. repeated lateral loading of insulators mounted to a rigid base.

Computational models will be developed using state-of-the-art Finite Element (FE) modeling and calibrated using the existing experimental data on porcelain insulators. Such FE models will provide means for further investigation of variable elements that affect seismic response and provide means for developing standards that go beyond physical testing limitations. The computational models will provide the framework for developing a “hybrid” simulation approach for insulators, by combining numerical modeling with actual testing of specimens reducing testing costs significantly.

For both porcelain and composite insulators, the project will:

- Develop detailed and simplified FE computational models and calibration.
- Conduct tests using both quasi-static and hybrid simulation approaches.
- Evaluate experimental results tests, comparing findings from test approaches, and re-evaluating the FE computational models.
- Develop acceptance criteria for the case when insulators are used in a seismic qualification test.
- Develop appropriate factors of safety (FS) for different load conditions.
- Draft recommended language for inclusion in future revisions of IEEE Standard 693.

Why It Matters

Substation post insulators are key components in a transmission system. In the event of a significant earthquake, failure of these components can cause a severe disruption of electric service. Replacing damaged insulators is expensive and labor-intensive, and can significantly delay recovery of power after a disruption. Past failures during seismic events have made it clear that current standards are inadequate: manufacturers are building post insulators 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 insulators 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 insulators, will reduce the likelihood of insulator failures, and will improve the recovery response to a seismic event.

{More details}

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Participating Organizations

Principal Investigator:

University of California, Berkeley, Pacific Earthquake Engineering Research (PEER) Center

Research Advisers:

Los Angeles Department of Water and Power

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

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Reports

Final Report: *Analysis of the Seismic Performance of Substation Post Insulators* (Not yet available)

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