



TIP 316: Combined Horizontal-Vertical Seismic Isolation System for High-Voltage Power Transformer

Context

So far, seismic base isolation systems developed by BPA research and implemented for high-voltage power transformers only provide protection against the horizontal components of earthquake motion. The vertical ground motion is transmitted unchanged or even in some cases, magnified.

Description

This project continues development of a high confidence procedure for determining the probability of failure for high voltage transformers in three installation configurations: Not base isolated, Base isolated for horizontal motion only, and Based isolated with a combined system for horizontal and vertical motions. The refined failure probability procedure takes into account different ground motion intensities, spectral shapes, near-fault ground motion effects, and modeling uncertainties of seismically isolated transforms.

This project demonstrated the effectiveness of a practical 3-dimensional seismic isolation system for use with high-voltage power transformers.

The research plan was as follows:

Study Options, Development of Concepts, Selection of Viable Systems

The mechanics of alternate isolation systems were studied so that the best (or optimum) configurations were achieved and then studied for their seismic isolation effectiveness for high-voltage power transformers. The study demonstrated the benefits and drawbacks of each option.

Design, Build and Test on the Shake Table a 3D Seismic Isolation System with a Model of a high-voltage power transformer.

Analytical models of the tested system were developed to compare results to the experimental data, thus validating the models.

Benefits

High-Voltage Power Transformers are seismically vulnerable. Base isolation is the ideal solution to protect this critical infrastructure component. This research advances base isolation technology for the protection of high-voltage power transformers, particularly in locations where the vertical acceleration component is significant and important in the implementation of transformer base isolation.

Accomplishments

Project developed a combined horizontal and vertical acceleration isolation system that:

- Provides significant reduction in the earthquake input motions (horizontal and vertical) to the high-voltage transformer ;
- Can be applied to high-voltage power transformers for both retrofit and new installations;
- Ensure sufficient rigidity for service loads;
- Ensure that rocking response is minimized or eliminated in order to prevent additional acceleration response due to rotation.

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Project Start Date: October, 2014

Project End Date: September, 2019

Deliverables

Deliverables include the following reports:

1. Horizontal base isolation solution for high-voltage transformers

- Technical Report NCEER-11-0003, Proceedings of the Workshop on Improving Earthquake Response of Substation Equipment, September 19, 2011
- Technical Report MCEER-11-0006, Modeling and Seismic Performance Evaluation of High Voltage Transformers and Bushings, October 3, 2011
- Technical Report MCEER-12-0002, Seismic Protection of Electrical Transformer Bushing Systems by Stiffening Techniques, June 1, 2012
- Technical Report MCEER-16-0006, Seismic Isolation of High Voltage Electrical Power Transformers, November 2, 2016
- Base Isolation Selection Tool, Spreadsheet

2. Vertical base isolation solution for combination with the horizontal isolation component

- Technical Report MCEER-16-0010, Procedures and Results of Assessment of Seismic Performance of Seismically Isolated Electrical Transformers with Due Consideration for Vertical Isolation and Vertical Ground Motions Effect, December 31, 2016
- Technical Report MCEER-17-0007, Development and Validation of a Combined Horizontal-Vertical Seismic Isolation System for High-Voltage Power Transformers, November, 3, 2017

3. Tool to determine the probability of failure of a high-voltage transformer without base isolation

- Technical Report, Probabilistic Seismic Assessment of Non-Seismically Isolated Electrical Transformers, July 14, 2018
- Technical Report 9-23-2019, Further Results of the Assessment of Performance of Seismically Isolated Electrical Transformers
- Probability of Failure Analysis Tool, Spreadsheet

A project close-out meeting was held at University of Buffalo, Buffalo, NY, Sept 4th -6th 2019. Key findings from the project and final deliverables were presented.

Links

Technical papers and reports from the project closeout meeting are available from the MCEER website www.buffalo.edu/mceer/catalog

Related Projects

TIP 354: Substation Seismic Performance with Supplemental Damping Devices

TIP 291: Substation Seismic Performance

TIP 278: Transformer Bushing Performance

TIP 156: High Voltage Power Transformer Base Isolation Technology and Implementation

TIP 25a: EPRI P37 Supplemental: Substation Seismic Studies

Participating Organizations

University at Buffalo, State University of New York



For More Information Contact:

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Conclusions

Key findings from the project:

1. Base isolation of high-voltage electrical transformers is a valid option to reduce damage during major earthquakes
2. Develop and test a cost efficient two component, Horizontal and Vertical, base isolation option for high voltage electrical transformer seismic protection
3. Developed tools to assess non-isolated transformers, and for the preliminary design of base isolation requirements

This project has directly led to implementation of base isolation systems in seismically active locations:

1. Two BPA projects to base isolate high-voltage transformers: Fairview substation FY2020 (depending on COVID 19) and Alvey substation 2021
2. Because of this research there are 5 based isolated transformers in the PNW (3 installed and one currently being designed by Seattle City Light, and 1 installed and one currently being designed by Centralia City Light)
3. In California, transformers are being base isolated for the new Trans-Bay cable project with the result of this research project
4. Chile, a high powered telescope is using the base isolation system developed by this project
5. California, a new major hospital is using the base isolation system developed by this project.

